ANNIVERSARY NUMBER FOR THE ASSOCIATION OF INDUSTRIAL MEDICAL OFFICERS

VOL. 13 NO. 3 JULY, 1956

BRITISH JOURNAL OF INDUSTRIAL MEDICINE

EDITOR
RICHARD SCHILLING

ASSISTANT EDITORS
J. C. GILSON L. G. NORMAN

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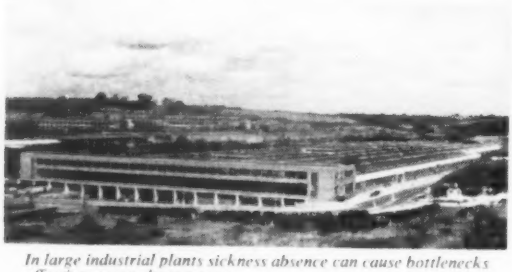

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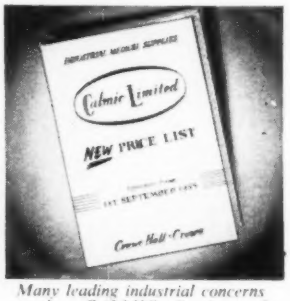

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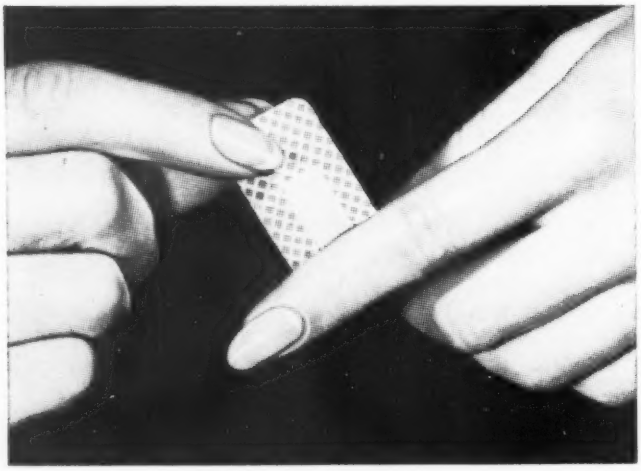

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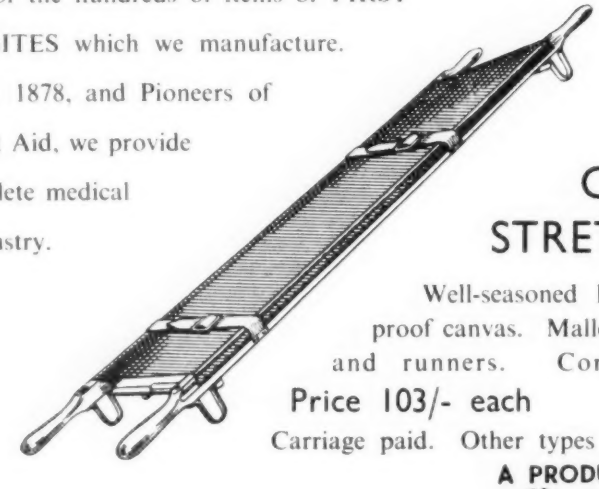

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Brit. J. industr. Med., 1956, **13**, 155.

Charles Turner Thackrah (1795-1833)
From an original painting in the Medical Library of the University of Leeds

Sir Arthur Whitelegge (1852-1933
From an original photograph

Sir Thomas Legge (1863-1932)
From an original photograph in the Wellcome Historical Medical Museum

SIXTY YEARS OF INDUSTRIAL MEDICINE IN GREAT BRITAIN

BY

ANDREW MEIKLEJOHN

From the Department of Industrial Health, University of Glasgow

On September 27, 1956, the Association of Industrial Medical Officers meets in London to celebrate its coming of age. The event is an appropriate occasion on which to recall briefly the progress of industrial medicine in Great Britain during the past 60 years.

Historical

Commencing with the Health and Morals of Apprentices Act, 1802, Parliament, through a succession of statutes, established its right to intervene in the regulation of employment in factories. Concurrently workmen won the right to combine in trade unions to safeguard their conditions of labour. As a result, over the century, hours of labour were abridged, the conditions of employment of women and children—the protected classes—were regulated, and education was extended among the working classes through schools and mechanics' institutes. By 1897, the year of Queen Victoria's Diamond Jubilee, Britain had become the leading industrial and commercial nation in the world. The machines, earlier regarded as the enemy of the manual worker, had resulted in great material wealth and prosperity, seemingly capable of limitless expansion. But over this glittering achievement and prospect there crept a dark increasing shadow: the factories were causing death and invalidism through accidents and disease. As a measure of alleviation workmen's compensation legislation was enacted, while Factory Acts were increasingly directed towards the promotion of safety, health, and welfare. Meanwhile legislation for non-factory workers, in the mines, in transport, in agriculture, and in shops and offices was trailing slowly in the rearguard of the Factory Acts.

Sixty Years Back

In March, 1896, Dr. Whitelegge (later Sir Arthur), County Medical Officer of Health of the West Riding of Yorkshire, was appointed Chief Inspector of Factories under the Home Office. He is the only medical man ever to occupy this position. Among his contemporaries his appointment was enthusiastically acclaimed for he had established a reputation not only as a great physician in preventive medicine but also as an outstanding administrator. Furthermore, in his daily work in the West Riding Whitelegge had walked in the steps of the master, Dr. Charles Turner Thackrah of Leeds. Two years

later, in 1898, Dr. Legge (later Sir Thomas) was appointed to be the first Medical Inspector of Factories. As proved by immediate developments, which were ultimately to influence the progress of industrial medicine in Great Britain and throughout the world, the times were fortunate in these leaders. Sixty years on, we are proud to salute their memory and achievements.

Advance through Legislation

In the 60 years between 1896 and 1956 perhaps the greatest single contribution to the advance of industrial medicine was made through legislation, based on the researches and recommendations of such notable leaders as Oliver, Goadby, Legge, Cathcart, Vernon, Collis, and many others. The contribution of the Factory Department was outstanding and a fitting continuation of the pioneer work of Howell, Horner, Rickards, and Saunders, the original four inspectors of factories, who were appointed in 1833. It would be wrong, however, to think entirely in terms of Factory Acts and Mines Acts and associated Orders and Regulations. These were directed to safety, health, and welfare, but they were supplemented by Workmen's Compensation Acts (now Industrial Injuries) and the Disabled Persons (Employment) Act, 1944.

The first Workmen's Compensation Act was passed in 1897. It related solely to injury by accident. In 1906 the Act was extended to cover industrial diseases of which six were named. These were poisoning by lead, mercury, arsenic, phosphorus; and anthrax and ankylostomiasis. The Home Secretary was empowered to add to these scheduled diseases (now prescribed diseases) and this immediately led to pressure by the workers and their unions for the inclusion of other trade diseases. Thus it became necessary to establish tests whereby industrial diseases could be distinguished from diseases in general. The first series of tests was formulated by the Samuel Committee (Home Office, 1907) and the subject has since been reviewed by committees under the chairmanship of Holman Gregory (Departmental Committee on Workmen's Compensation, 1922), Rolleston (Home Office, 1933), Dale (Ministry of National Insurance, 1948), and Beney (Ministry of Pensions and National Insurance, 1955). The discussions have involved consideration of such problems as connotation of "disease", "specific to the employment in the individual patient", and "balance of probability" test. It has also been necessary to distinguish between disease by accident and disease by gradual process. Among the diverse diseases which have been dealt with are silicosis, Weil's disease, chronic poisoning by carbon monoxide, tuberculosis, Raynaud's phenomenon, and finally cadmium poisoning. Prescribed diseases at present number 41, in addition to byssinosis and pneumoconiosis, which are covered by special legislation. Workmen's compensation, apart from Common Law liability, is now embraced in the National Insurance (Industrial Injuries) Act, 1946.

Despite the annual toll of death and accidents at work, it is remarkable that no constructive national effort for the well-being of disabled and handicapped persons was instituted until after World War I, when attention, or rather emotion, was excited by the return to civil life of thousands of men broken mentally and physically. The first attempt at a scheme for employment was the King's Roll of Disabled, but the charter of the disabled (the Disabled Persons (Employment) Act, 1944) was not achieved till 25 years later. While meantime the profession and the hospitals generally have assisted in promoting rehabilitation, special contributions have been made by the Royal Albert Docks Hospital, London, and the Birmingham Accident Hospital; by the rehabilitation workshops at Austin and Vauxhall Motors; by Remploy and by Roffey Park. For the patient a most valuable advance has been made in that the emphasis has been transferred from disability and incapacity for work to residual ability and capacity. Towards this Stewart (1939), and the techniques of job analysis associated with the work of Hanman (1951), have made a substantial contribution.

All this notwithstanding this specific industrial legislation must not be regarded in isolation, for the workers have shared with all in the advances which have resulted from public health legislation, education acts, and the comprehensive provisions for national health and welfare.

Medical Services in Industry

The statutory medical services represent the measures for enforcement of the Factories Acts and related Orders and Regulations. They are mainly the concern of the appointed factory doctors (originally the certifying surgeons) under the supervision of the medical inspectors of factories. The Factory Department has constantly endeavoured to extend and render more effective this medical supervision and since 1948 there have been important extensions, particularly in relation to the health examinations of young persons and supervision in premises not previously included in the definition of a factory. The pneumoconiosis panels undertake initial and periodical examinations in specified occupational groups in dusty industries, and since

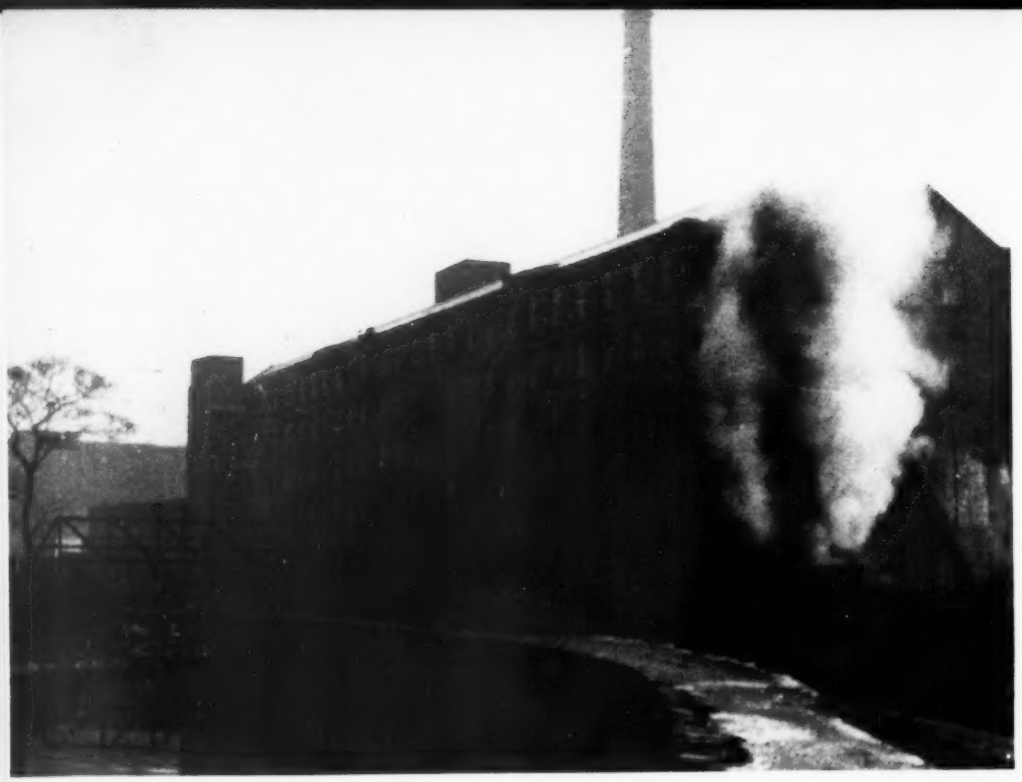
Reproduction of a water-colour of Newcastle-on-Tyne painted by Sir Thomas Legge

1952 a scheme has been developed for the examination of new entrants under the age of 21 years to the mining industry. These examinations are conducted by the medical officers of the National Coal Board.

The passing of workmen's compensation legislation, as previously recounted, led almost immediately to an increase of doctors in industry but almost entirely on a consultative basis. Their purpose was not primarily the care of the workmen nor the prevention of accidents and diseases but to help the employers to rebut claims for damages. Inevitably the workers and their trade unions came to regard the doctor as the employers' man and as such he excited hostility. There can be little doubt that this association of doctor and employer against the workman hindered the employment of the doctor for more beneficent services in industry. Even now the antagonism has not been entirely surmounted. However, in connexion with welfare services a few firms did succeed in introducing full-time doctors into their organizations. But as has so often happened in so many fields of human endeavour war has provided the necessary stimulus to advance. Thus the first world war focused attention on such problems as industrial fatigue, nutrition, T.N.T. poisoning, and the employment of women. These problems led to the establishment in 1915 of the Health of Munitions Workers Committee and in 1918 of the Industrial Fatigue (now Health) Research Board (Wilson, 1921, 1922). This was the beginning of the modern development of medicine in industry. Throughout the war there was an increase in medical services in industry, particularly in ordnance factories, but their employment soon declined with the coming of peace. However, certain progressive managements, especially in the chemical and engineering industries, had realized the potential advantages of medical supervision within the factory, and so a new group of doctors, if not a new branch of medicine, emerged.

The Association of Industrial Medical Officers

By 1935 the number of doctors employed in industry had so increased that a few leaders and their associates, chief among them Professor W. W. Jameson (later Sir Wilson) of the London School of Hygiene, Dr. Howard Mummery, and Dr. Donald Stewart decided that the time had arrived for the formation of a society of doctors employed full-time in industry. This was the origin of the Association of Industrial Medical Officers, which held its first meeting in the London School of Hygiene on September 27 and 28, 1935. Altogether 18 members, of a total of 35, attended. Dr. Howard Mummery was elected chairman. Dr. Leonard Lockhart opened a discussion on the future development of industrial medicine, at the conclusion of which it was agreed that at the next meeting Dr. T. Garland should introduce the topic of the relationship of the industrial medical officer to the general



A cotton mill on the Manchester-Oldham Canal built in the nineteenth century

[*By courtesy of Bryan Harvey*

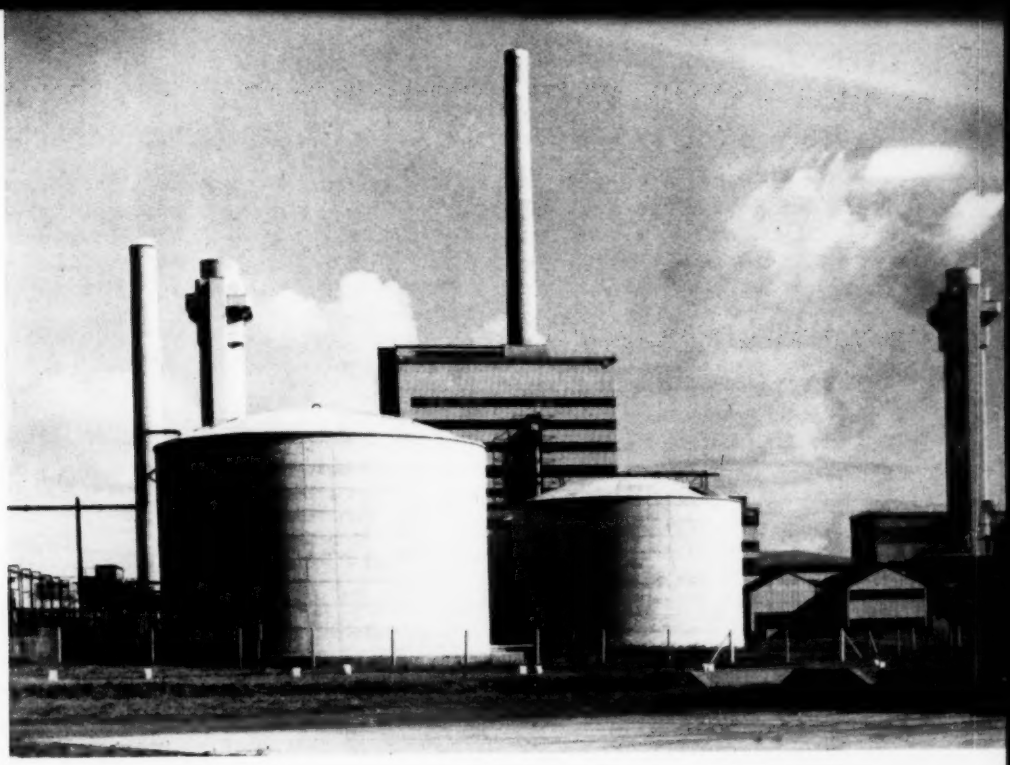
practitioner. Membership of the Association steadily mounted as the number of doctors in industry increased. The increase of medical services in industry was greatly accelerated and advanced by the Second World War, especially after the fall of Dunkirk. Ernest Bevin, Minister of Labour and National Service, was the power behind this development and was ably supported by members of the Association, among whom we recall with admiration Sir David Munro, Dr. J. C. Bridge, and Dr. A. J. Amor. These were the leaders, but scores of others followed the unspectacular routine of keeping men and women—our civilian army—fit to endure the toil of long hours in the black-out and often under almost unremitting attack from the air. The shelters were there, but the workmen stuck to their benches.

Meanwhile, membership of the Association was extended to include part-time medical officers. At present the total membership is approximately 800 of whom some 400 are full-time. Alongside this development there has been an even greater increase in the number of nurses employed in industry, of whom 3,000 are State registered, including 900 who hold the certificate in industrial nursing.

In the constitution of the nationalized industries, it was recommended that the organization should include medical services. Thus the National Coal Board has established a full-time medical service directed by a chief medical officer assisted by 65 doctors, 300 nurses, and 20,000 first-aid men for the 700,000 men employed in coal-mines throughout Britain.

In 1948 the Ministry of Labour and National Service enquired into the extent, distribution, and content of medical services in factories. The results revealed that there existed a fairly extensive but patchy and uncoordinated occupational health service at the larger factories, but that there was little provision for small factories of which there are almost 203,000 (80% of total factories) which each employ less than 26 workers. Furthermore, employments outside factories—agriculture, transport, shops, and offices—were scarcely touched.

In factories where health services have been developed the scope and practice has extended considerably over the years. Compensation cases nowadays are usually referred to outside consultants and specialists, while the members of the health team devote themselves to general health and accident care, selection and placement of workers based on initial and periodical examinations, and rehabilitation. In addition these activities may be supplemented by physiotherapy, chiropody, dental and ophthalmic services, together with radiological, electrocardiographic, and laboratory facilities. This does not signify any attempt to replace or encroach on the sphere of the general practitioner or the clinic services of the hospitals, but is simply an endeavour to provide such facilities for accurate diagnosis and efficient immediate treatment as may enable the workman to continue on the job. In consultation with the workman's own doctor continued treatment may be provided at work. Basically the purpose is prevention of accidents and



An atomic energy factory in England built and in production after the second World War

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disease while alleviating the proximate and remote adverse effects of injury or disease.

Industrial Toxicology

At the turn of the century industrial toxicology was comparatively simple and was concentrated on poisoning by lead, phosphorus, mercury, and arsenic, all in inorganic form. A change, however, was in progress, whereby the organic chemist was placing an ever-increasing number of compounds at the disposal of a wide variety of industries. Interest was in their industrial and commercial value rather than in their toxic effects on workmen. World War I dramatically revealed their first assault in the form of T.N.T. poisoning among munition workers. This ultimately focused attention on the deleterious effects of organic chemicals on the liver and blood-forming organs. The attack increased and intensified through the use of aromatic and aliphatic hydrocarbons; and organic lead, mercury, and phosphorus, particularly with reference to insecticides and pesticides. To these in turn were added the hazards of ionizing radiations and poisoning by rare metals including beryllium, vanadium, selenium, and cadmium. And all the while an old enemy of the workman, silicosis, advanced; asbestosis was added and pneumoconiosis of coalworkers, distinguished as a separate pathological entity, brought disaster to the coalfields, particularly in South Wales. Industrial dermatitis increased and in the case of pitch and tar was associated with epitheliomatous ulceration. The results, however, were not all adverse for many of these risks were in due course effectively prevented or controlled. Lead poisoning in pottery manufacture and in the production of electric accumulators was successfully combated; silicosis in metal grinders, sand-blasters, and certain china workers was prevented: the risks of ionizing radiations and beryllium were controlled. All this was achieved by team work of scientists, doctors, and engineers and made effective through legislation, which, however, sometimes needed the prop and pioneer efforts of voluntary medical services as exemplified by Lane's work in the lead accumulator industry (Lane, 1949) and Jenkins' work in the gas industry (Jenkins, 1948).

Research

Research nowadays is regarded as an important measure of the vitality of a subject and its disciples. The record here both in fundamental and field studies is impressive, especially as in many instances it has been possible to translate the results into practical measures of prevention and control. As already remarked, the opening years of the century were dominated by the study of phosphorus poisoning, lead poisoning, and anthrax, in all of which Oliver and Legge played leading parts (Legge and Goadby, 1912; Oliver, 1908). Haldane (1904), Collis (1915), and Middleton (1936) instituted enquiries into dust diseases of the lungs, which led to the formation of the Industrial Pulmonary Diseases Committee of the Medical Research Council. Notable fundamental work on the aetiology and

pathology of dust diseases of the lungs was carried out by Kettle (1926), Belt and Ferris (1942), King (1945), Matthew Stewart (1933), Gloyne (1930, 1932), Gough (1947), and Gough and Wentworth (1949). Among field studies the investigations of Merewether (1933) on asbestosis; of Sutherland and Bryson (1929) and Sutherland, Bryson, and Keating (1930) on silicosis; of Doig and McLaughlin (1936, 1948) on siderosis; of Hart and Aslett (1942) and Fletcher (1948) and his colleagues of the Pneumoconiosis Research Unit at Cardiff into pneumoconiosis of coalworkers. All these contributions have gained international recognition.

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Industrial Health and Medical Teaching

Medical teaching on the influence of occupation on health and employment has generally been the affair of clinical teachers and so depended on the interest and knowledge of the individual teacher. All too often in such circumstances the subject received scant reference. Dr. Donald Hunter's unit at the London Hospital was a signal exception. Legge, according to Henry, advocated the need for better education in industrial medicine as part of the curriculum in medical schools, and he accepted lectureships on the subject at King's College, London, from 1920 to 1924 and at University College, London, from 1922 to 1929 and at Manchester University from 1920 until his death in 1932. I was one of his students at Manchester and can still recall the tall immaculate figure and the bright-coloured bow-tie just a trifle askew. He always entered the lecture-room—a modern Moses—carrying two immense folders which seemed to contain the whole corpus of English industrial law. His presentation was quiet and ever unpretentious but the student could not fail to realize the extent and intensity of his experience. As he walked before the benches, for he never used the rostrum, one felt that he was pacing the factory or foundry floor exchanging experiences with the workmen. Our notebooks pushed aside, we moved with him from factory to factory throughout Great Britain and all over Europe, studying the individual processes. But the mechanical side, albeit important, was incidental; our concern must be with skilled and busy craftsmen exposed to myriad risks. These risks constituted the challenge; they must be prevented and the responsibility in the matter devolved almost entirely on the employer. And all the while he excited in us something of the beauty of craftsmanship of Chinese porcelain and mediaeval stained glass. By any standard, professional skill, scholarship, social purpose and, above all, sympathy and integrity, Legge was a great physician. Is it too much to hope that some day the London School of Hygiene may find a place on its façade to carve his name among the great ones already memorialized there?

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certifying surgeon of mature experience he had sound qualifications for the post. However, he received little academic support and even less financial backing from industry. So after a very brief existence the department ceased, leaving one memorial, a textbook on occupational medicine with special reference to the psychological aspects.

The next venture came in 1945 when the Nuffield Foundation offered substantial funds to the universities of Manchester, Durham, and Glasgow to enable them to establish departments of industrial health. Manchester and Durham founded professorships and Glasgow a lectureship in the department of Public Health and Social Medicine. Edinburgh University from its own resources established a lectureship, while other medical schools introduced lectures on industrial health into the courses of Public Health and Social Medicine for undergraduates and postgraduates. A further step was taken by the institution of the Diploma in Industrial Health (D.I.H.) by the Society of Apothecaries, who were followed by the Conjoint Board for England and Wales, the Royal Faculty of Physicians and Surgeons of Glasgow, and the University of Edinburgh. The qualifying course occupied a full academic year. For a variety of reasons the necessary number of students did not materialize and so after a few years Edinburgh discontinued both the lectureship and the diploma. The University of Manchester has now intimated its intention to discontinue its department in its present form. There is now no full-time course save at the London School of Hygiene where the D.I.H. is combined with the D.P.H. on an elective basis. A part-time course is available at the Royal Institute of Public Health and Hygiene in London. Reviewing the work of its first 10 years the Nuffield Foundation indicated that the study of industrial health was among the less successful of its ventures. These facts, however, should not be interpreted as total failure, for, in fact, these departments have not been without success. This is proved by their contributions to research, to the training of doctors and nurses, and by their contributions to medical literature. There can be no dispute that industrial medicine has come to stay and signs, as exemplified by the setting up in 1955 of the Industrial Health Advisory Committee under the personal chairmanship of the Minister of Labour and National Service, proclaim advance. Among its advocates are the Royal College of Physicians of London (1944), the British Medical Association (1944), the Medical Practitioners Union, the Trade Union Congress, the Geneva (Home Office, 1949), and Dale (Industrial Health Services, 1951) committees. The universities must not abandon leadership in this field. Their need is to re-examine the problem and to devise means to promote the development of medicine in industry. The issue is no less than where do the universities stand in the future development of preventive medicine; in the conservation and promotion of health as opposed to the arrest and cure of disease?

The Literature

One measure of the vitality of a subject is the extent and quality of its literature. The first textbook of the period under review was "Dangerous Trades" by Sir Thomas Oliver, which was published in 1902. "Industrial Maladies", based on experiences at the Factory Department, by Sir Thomas Legge appeared posthumously in 1934. Others followed, but recently two outstanding books have been published: "Industrial Medicine and Hygiene" (3 vols.) edited by Merewether (1954) and "The Diseases of Occupations" by Hunter (1955). These have greatly advanced the prestige of British occupational medicine.

Among periodicals the *British Journal of Industrial Medicine* founded in 1944 is highly regarded throughout the world. Other periodicals serving specialized groups comprise the *Journal for Industrial Nurses*, the *Transactions of the Association of Industrial Medical Officers*, *Industrial Welfare*, and the *Industrial Law Review*. Finally it is of interest to note the increasing number of articles and lectures on occupational medicine subjects in the general medical press and at conferences.

Conclusion

Early this year Sir Wilfrid Garrett, formerly H.M. Chief Inspector of Factories, following a visit to the Potteries, wrote: "The potters' shops (you will not believe it) are clean." That simple comment may signify more for the future safety, health and welfare of the industrial worker and his dependants than concurrent advances in surgery and medicine. Final achievement will not come until, as stated by Merewether, "industrial hygiene (health) is not the pursuit of the few, but the practice of the multitude". And therein lies the responsibility of the universities which train doctors, scientists, and engineers.

soft-faced hammer ... another the man who is the confidant of all in trouble. Some work because work is a habit, some because it gives them opportunities for day-dreaming, and yet others because ambition is the spur. The philosophy and creed of Calvinism which regards work as a moral and religious duty has a diminishing number of devotees in western Europe though they may still be found in Scotland and the Low Countries. In Russia and elsewhere the dynamism of the Communist faith exerts on party members much the same kind of influence. All or any of these considerations apply to every form of work except perhaps that of the creative artist whose motivation is an inner compulsion which often he does not understand. For him there is no divorce between work and leisure. Creative activity is his life and the power of it is irresistible.

... subject is not new and has called ... fathers and brethren throughout all generations. But what may be new is the increasing number of men and women who are specializing in the application of medicine to industry. The organization of industrial medicine is the inevitable reply to a clamant social need—just as public health was organized in the nineteenth century to combat the evils resulting from urbanizing a rural society. The present development of industrial medicine behoves us to examine afresh our vocation. Why do we do this work?

Inevitably and fortunately in an expanding enterprise there are always a few men who are obsessed and inspired by its ideals and possibilities. That our own branch of the profession in this country is producing such men cannot be doubted. We need not fear for our future leadership in the years which lie immediately ahead. But what impels the growing

number of younger men and women to practise medicine inside industrial groupings ? One of the glories of working within industry is the intense satisfaction to be derived from working as a member of a team—a team so diverse in its interests as to include works managers, engineers, chemists, personnel managers, nurses, shop stewards, and many others. The contribution made in working and associating with colleagues in a common task may be considerable, the contribution one receives is very great. Its results are not only of value to the community but have personal implications also. Not infrequently the doctor in a factory slips into that special little niche which only he can fill and the privilege of the unique contribution which only he can make is infinitely rewarding. Chaucer knew him:

> " With us ther was a Doctour of Phisyk.
> In al this world ne was ther noon him lyk."

We are fortunate in the great tradition of medicine which we inherit—a tradition of integrity and of independence, a tradition of kindliness and often of self-sacrifice. Even today practitioners of medicine derive immense satisfaction because they are not just another type of technician. This position must be fought for by maintaining the traditionally high standard of personal conduct. The techniques of our profession continue to multiply but their limits are set by one over-riding consideration, the inherent worth of each individual. No medical practitioner would allow men to work in an atmosphere of unknown toxicity merely to discover what the effect might be. The acceptance of the essential importance of the individual is part and parcel of our inheritance as doctors, powerfully reinforced by the Christian religion. However ineffective that religion may appear to be today there is no doubt of its influence in the formative days of British medicine. There is a danger that in the need for organization in a complex society the individual may be sacrificed. Humanism pays lip service to the idea that human personality has supreme value, but that idea may soon be submerged in any planned society. We as doctors are constantly in touch with people in need, always aware of human frailty, but ever conscious of the potentialities of goodness and occasionally of greatness in those amongst whom we work. We should remind ourselves from time to time of the doctrine of the sanctity of personality in which every liberal society has its roots. Consciously or unconsciously doctors accept the standards implicit in all this but within the limits set by our acceptance of these standards we are governed by the considerations which apply to any trade or profession. We must preserve our idealism but there is no place in industrial medicine for a sentimental paternalistic approach. We must always strive not only to achieve the highest competence of which we are capable but we should be constantly seeking new techniques and through them to make whatever contribution we can to our community. That is but our common social duty. As Dorothy Sayers (1941) puts it:—

> " The way in which the work is done is governed by no sanction except the good of the work itself: and religion has no direct connection with that except to insist that the workman should be free to do his work well according to its own integrity."

Later she illustrates this in discussing the choice of actors for a religious play and continues "the right kind of actor with no morals would give a far more reverent and seemly performance than a saintly actor with the wrong technical qualifications". No doubt the technically qualified saint would be ideal. But, unfortunately, they are very rare in any situation. It behoves us, then, not only to be technically efficient at the work to which we have set our hands but because of its nature we should see before us the vision of industrial environment in which we and our fellows can, if we will, find freedom in service. In the first century, St. Paul knew that concept and found his freedom in his bondage to an ideal.

Men and women are in an environment (psychological as well as physical) which is constantly changing; there is generally a delay in the adaptation, which emphasizes the importance of the role played by doctors in industry. Hand skills are being replaced by machine skills; in many respects the " boss " has become impersonal; and there is often no identifiable focus for loyalty, except perhaps the shop steward. The working group is frequently subjected to new processes or to a change in routine. The most resilient personalities do not appear to be affected by these changes. However, Russell Fraser (1947) found that 9% of men and 13% of women in a sample of 3,000 industrial workers had suffered from definite disabling neurotic illness and that this type of illness caused 25-33% of all sickness, which again emphasizes the importance of the task that doctors have been called upon to play in industry. Our vocation lies not only in psychological medicine but also in general and social medicine. One man may find that the prime need of the industry in which he is engaged is the organization of a casualty service, another may be concerned with dust, and yet another with toxicological or similar hazards. The variety is almost infinite but all the time the concern is for individual men and women. Happy is the family doctor who combines general practice

with occupational medicine, for he is in the unique position of knowing many of his patients not only as members of family groups in which they live a relatively small part of their lives (for families grow up and disperse) but of changing yet continuing industrial groups as well. The influences which act on people during their working lives can be known only to those who have experienced or investigated them. Opportunities for research are abundant and as a rule the necessary facilities are available. Before we can prescribe for the individual we must know the cause of his breakdown and the prescription is often one which only the factory doctor can make—the modification of a process, the alteration of a man's working hours, the transfer to a more congenial group. The bounds of ignorance are gradually being pushed back and in these advances doctors in industry have played and are playing a notable part. It is a part which is the quintessence of our vocation.

Because individuals aggregate to form groups in which they are subjected to similar environmental influences, the reactions of these groupings must be studied. Morris (1955) points out that "epidemiology", which is one aspect of this study,

> ". . . . supplements the clinical picture: by asking questions that cannot be asked in clinical study—about the health of the community and of sections of it, present and past; by setting clinical problems in community perspective, describing their behaviour as group not individual phenomena, indicating their dimensions and distributions, and how much, and where, action is needed; . . . "

Earlier in his paper Morris suggests a number of problems which require elucidation. Some of these are on our own doorstep—" the effect of more married women going out to work, of less physical activity in work and more bodily sloth generally; of multiple chemical and physical exposures, known and potentially hazardous; . . . "—not to speak of occupational dermatitis and its relationship, if any, to emotional instability, the various aspects of the incidence of accidents, of chronic bronchitis, of the effects of noise, and a host of others. Many contributions have been made on some of these and other subjects, by doctors in industry. The opportunities, the privilege, and the exhilaration of isolating one little iota of truth in the vast welter of surmise, are open to every practitioner of medicine in industry. The factory doctor knows his patients intimately as individuals but he can, if he will, know them too as members of a social group.

There is a separation if not quite a divorce of clinical medicine from social medicine today. It may be that those of us who accept clinical responsibilities (as perforce to some extent we must) and at the same time have the maintenance of the health and welfare of the industrial population while at work, as our duty, will be agents in their reconciliation.

The approach, from an interest in individuals to a concern for coherent groups, has been common to most of our predecessors. To realize that the tradition persists, one has only to think of Henry (1946) whose interest in cancer of the scrotum as a clinical problem led to his study of it as an occupational one—and to its virtual elimination. In more recent years a growing number of men and women have entered our speciality from the opposite direction. With an interest in public health and the behaviour of aggregations of people, they have been led to the industrial field. Their contribution to the techniques of observation and analysis are of the utmost value. Nevertheless occupational medicine remains very largely a clinical subject presenting a wide variety of facets.

It is, unfortunately, true that as in every other branch of the profession there are a few who are so immersed in the routine of the job that they have neither the time nor the inclination to sit back and think of the essential significance of their work. But the work they do is still important. What they miss is the inspiration of knowing that they belong to a group of men and women who are dedicated to the idea that the traditions and the techniques of medicine can contribute immeasurably to the health and happiness of the industrial community. Occupational medicine as a vocation beckons to it technically good doctors, generous in their sympathies, liberal in their sentiments, humble in their ignorance, adventurous in their seeking, and courageous when, as sometimes happens, they are misunderstood by those whom they serve.

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In 1934 the University of Birmingham realized the need for more specialized instruction than that provided by the clinical departments. A readership was established and Dr. Howard Collier became the first and, as it proved, the only holder of the appointment. As a general practitioner and

certifying surgeon of mature experience he had sound qualifications for the post. However, he received little academic support and even less financial backing from industry. So after a very brief existence the department ceased, leaving one memorial, a textbook on occupational medicine with special reference to the psychological aspects.

The next venture came in 1945 when the Nuffield Foundation offered substantial funds to the universities of Manchester, Durham, and Glasgow to enable them to establish departments of industrial health. Manchester and Durham founded professorships and Glasgow a lectureship in the department of Public Health and Social Medicine. Edinburgh University from its own resources established a lectureship, while other medical schools introduced lectures on industrial health into the courses of Public Health and Social Medicine for undergraduates and postgraduates. A further step was taken by the institution of the Diploma in Industrial Health (D.I.H.) by the Society of Apothecaries, who were followed by the Conjoint Board for England and Wales, the Royal Faculty of Physicians and Surgeons of Glasgow, and the University of Edinburgh. The qualifying course occupied a full academic year. For a variety of reasons the necessary number of students did not materialize and so after a few years Edinburgh discontinued both the lectureship and the diploma. The University of Manchester has now intimated its intention to discontinue its department in its present form. There is now no full-time course save at the London School of Hygiene where the D.I.H. is combined with the D.P.H. on an elective basis. A part-time course is available at the Royal Institute of Public Health and Hygiene in London. Reviewing the work of its first 10 years the Nuffield Foundation indicated that the study of industrial health was among the less successful of its ventures. These facts, however, should not be interpreted as total failure, for, in fact, these departments have not been without success. This is proved by their contributions to research, to the training of doctors and nurses, and by their contributions to medical literature. There can be no dispute that industrial medicine has come to stay and signs, as exemplified by the setting up in 1955 of the Industrial Health Advisory Committee under the personal chairmanship of the Minister of Labour and National Service, proclaim advance. Among its advocates are the Royal College of Physicians of London (1945); the British Medical Association (1941); the Medical Practitioners Union; the Trade Union Congress; the Gowers (Home Office, 1949) and Dale (Industrial Health Services, 1951) committees. The universities must not abandon leadership in this field. Their need is to re-examine the problem and to devise means to promote the development of medicine in industry. The issue is no less than where do the universities stand in the future development of preventive medicine; in the conservation and promotion of health as opposed to the arrest and cure of disease ?

The Literature

One measure of the vitality of a subject is the extent and quality of its literature. The first textbook of the period under review was " Dangerous Trades " by Sir Thomas Oliver, which was published in 1902. " Industrial Maladies ", based on experiences at the Factory Department, by Sir Thomas Legge appeared posthumously in 1934. Others followed, but recently two outstanding books have been published: " Industrial Medicine and Hygiene " (3 vols.) edited by Merewether (1954) and " The Diseases of Occupations " by Hunter (1955). These have greatly advanced the prestige of British occupational medicine.

Among periodicals the *British Journal of Industrial Medicine* founded in 1944 is highly regarded throughout the world. Other periodicals serving specialized groups comprise the *Journal for Industrial Nurses*, the *Transactions of the Association of Industrial Medical Officers*, *Industrial Welfare*, and the *Industrial Law Review*. Finally it is of interest to note the increasing number of articles and lectures on occupational medicine subjects in the general medical press and at conferences.

Conclusion

Early this year Sir Wilfrid Garrett, formerly H.M. Chief Inspector of Factories, following a visit to the Potteries, wrote: " The potters' shops (you will not believe it) are clean ". That simple comment may signify more for the future safety, health and welfare of the industrial worker and his dependants than concurrent advances in surgery and medicine. Final achievement will not come until, as stated by Merewether, " industrial hygiene (health) is not the pursuit of the few, but the practice of the multitude". And therein lies the responsibility of the universities which train doctors, scientists, and engineers.

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OCCUPATIONAL MEDICINE AS A VOCATION

BY

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Those of us who are engaged in the practice of medicine within industry have at some time been forced to ask ourselves, " Why do men work ? ", and no single simple answer emerges. Most of us work because work is an economic necessity. " In the sweat of thy brow shalt thou eat bread (Genesis iii : 7)." Work is a condition of man's existence but almost inevitably most of us would avoid it if we could. That we do not make more strenuous efforts to do so is probably because although labour is not sweet its fruits often are. The satisfaction of doing a job well, the sense of achievement, or the genuine commendation of a supervisor can compensate for hours of drudgery. But these rewards are rare and what makes work more bearable for most men and women day in and day out for years on end, are its by-products—the companionship of the group, the possibility of earning enough to buy a television set or some adjunct to a hobby or a better education for a boy at home. Some get through the day's work not because they enjoy it but because inside the working group they hold a recognized and unique place into which they or almost they alone can fit. One character inevitably becomes a shop steward, another the wag who sends the new apprentice for " sky-hooks " or a " soft-faced hammer ", another the man who is the confidant of all in trouble. Some work because work is a habit, some because it gives them opportunities for day-dreaming, and yet others because ambition is the spur. The philosophy and creed of Calvinism which regards work as a moral and religious duty has a diminishing number of devotees in western Europe though they may still be found in Scotland and the Low Countries. In Russia and elsewhere the dynamism of the Communist faith exerts on party members much the same kind of influence. All or any of these considerations apply to every form of work except perhaps that of the creative artist whose motivation is an inner compulsion which often he does not understand. For him there is no divorce between work and leisure. Creative activity is his life and the power of it is irresistible.

The practice of medicine impinges on every facet of human life and since the dawn of medicine its practitioners have interested themselves in the relationship between occupation and health. Hippocrates (born 460 B.C.) well knew and described the toxic properties of lead. Galen (born 131 B.C.) referred to the diseases peculiar to miners, tanners, and fullers. Pliny the Elder (A.D. 23-79) described the masks worn by those employed in dusty trades. Paracelsus (1493-1541) wrote a monograph on *Miners' Sickness and Other Miners' Diseases* and in more recent times—the eighteenth century—Bernadino Ramazzini wrote his classic *De Morbis Artificum Diatriba*. Percival Pott described the scrotal cancer of chimney-sweeps, Willan the skin lesions of bakers, while later Thomas Percival of Manchester and Charles Turner Thackrah of Leeds were the prophets of Sir Thomas Legge who made industrial medicine his life work.

The present increased awareness of the relationship between occupation and health is mainly due to the rapid industrialization of modern society and to the ever-growing multiplication of specialities in all the arts and sciences, because of our restless haste to accumulate, and sometimes to use knowledge. The subject is not new and has called our fathers and brethren throughout all generations. But what may be new is the increasing number of men and women who are specializing in the application of medicine to industry. The organization of industrial medicine is the inevitable reply to a clamant social need—just as public health was organized in the nineteenth century to combat the evils resulting from urbanizing a rural society. The present development of industrial medicine behoves us to examine afresh our vocation, Why do we do this work ?

Inevitably and fortunately in an expanding enterprise there are always a few men who are obsessed and inspired by its ideals and possibilities. That our own branch of the profession in this country is producing such men cannot be doubted. We need not fear for our future leadership in the years which lie immediately ahead. But what impels the growing

number of younger men and women to practise medicine inside industrial groupings ? One of the glories of working within industry is the intense satisfaction to be derived from working as a member of a team—a team so diverse in its interests as to include works managers, engineers, chemists, personnel managers, nurses, shop stewards, and many others. The contribution made in working and associating with colleagues in a common task may be considerable, the contribution one receives is very great. Its results are not only of value to the community but have personal implications also. Not infrequently the doctor in a factory slips into that special little niche which only he can fill and the privilege of the unique contribution which only he can make is infinitely rewarding. Chaucer knew him:

> " With us ther was a Doctour of Phisyk.
> In al this world ne was ther noon him lyk."

We are fortunate in the great tradition of medicine which we inherit—a tradition of integrity and of independence, a tradition of kindliness and often of self-sacrifice. Even today practitioners of medicine derive immense satisfaction because they are not just another type of technician. This position must be fought for by maintaining the traditionally high standard of personal conduct. The techniques of our profession continue to multiply but their limits are set by one over-riding consideration, the inherent worth of each individual. No medical practitioner would allow men to work in an atmosphere of unknown toxicity merely to discover what the effect might be. The acceptance of the essential importance of the individual is part and parcel of our inheritance as doctors, powerfully reinforced by the Christian religion. However ineffective that religion may appear to be today there is no doubt of its influence in the formative days of British medicine. There is a danger that in the need for organization in a complex society the individual may be sacrificed. Humanism pays lip service to the idea that human personality has supreme value, but that idea may soon be submerged in any planned society. We as doctors are constantly in touch with people in need, always aware of human frailty, but ever conscious of the potentialities of goodness and occasionally of greatness in those amongst whom we work. We should remind ourselves from time to time of the doctrine of the sanctity of personality in which every liberal society has its roots. Consciously or unconsciously doctors accept the standards implicit in all this but within the limits set by our acceptance of these standards we are governed by the considerations which apply to any trade or profession. We must preserve our idealism but there is no place in industrial medicine for a sentimental paternalistic approach. We must always strive not only to achieve the highest competence of which we are capable but we should be constantly seeking new techniques and through them to make whatever contribution we can to our community. That is but our common social duty. As Dorothy Sayers (1941) puts it:—

> " The way in which the work is done is governed by no sanction except the good of the work itself: and religion has no direct connection with that except to insist that the workman should be free to do his work well according to its own integrity."

Later she illustrates this in discussing the choice of actors for a religious play and continues "the right kind of actor with no morals would give a far more reverent and seemly performance than a saintly actor with the wrong technical qualifications". No doubt the technically qualified saint would be ideal. But, unfortunately, they are very rare in any situation. It behoves us, then, not only to be technically efficient at the work to which we have set our hands but because of its nature we should see before us the vision of industrial environment in which we and our fellows can, if we will, find freedom in service. In the first century St. Paul knew that concept and found his freedom in his bondage to an ideal.

Men and women are in an environment (psychological as well as physical) which is constantly changing; there is generally a delay in the adaptation, which emphasizes the importance of the role played by doctors in industry. Hand skills are being replaced by machine skills; in many respects the " boss " has become impersonal; and there is often no identifiable focus for loyalty, except perhaps the shop steward. The working group is frequently subjected to new processes or to a change in routine. The most resilient personalities do not appear to be affected by these changes. However, Russell Fraser (1947) found that 9% of men and 13% of women in a sample of 3,000 industrial workers had suffered from definite disabling neurotic illness and that this type of illness caused 25-33% of all sickness, which again emphasizes the importance of the task that doctors have been called upon to play in industry. Our vocation lies not only in psychological medicine but also in general and social medicine. One man may find that the prime need of the industry in which he is engaged is the organization of a casualty service, another may be concerned with dust, and yet another with toxicological or similar hazards. The variety is almost infinite but all the time the concern is for individual men and women. Happy is the family doctor who combines general practice

with occupational medicine, for he is in the unique position of knowing many of his patients not only as members of family groups in which they live a relatively small part of their lives (for families grow up and disperse) but of changing yet continuing industrial groups as well. The influences which act on people during their working lives can be known only to those who have experienced or investigated them. Opportunities for research are abundant and as a rule the necessary facilities are available. Before we can prescribe for the individual we must know the cause of his breakdown and the prescription is often one which only the factory doctor can make—the modification of a process, the alteration of a man's working hours, the transfer to a more congenial group. The bounds of ignorance are gradually being pushed back and in these advances doctors in industry have played and are playing a notable part. It is a part which is the quintessence of our vocation.

Because individuals aggregate to form groups in which they are subjected to similar environmental influences, the reactions of these groupings must be studied. Morris (1955) points out that " epidemiology ", which is one aspect of this study,

> " . . . . supplements the clinical picture: by asking questions that cannot be asked in clinical study—about the health of the community and of sections of it, present and past; by setting clinical problems in community perspective, describing their behaviour as group not individual phenomena, indicating their dimensions and distributions, and how much, and where, action is needed; . . . "

Earlier in his paper Morris suggests a number of problems which require elucidation. Some of these are on our own doorstep—" the effect of more married women going out to work, of less physical activity in work and more bodily sloth generally; of multiple chemical and physical exposures, known and potentially hazardous; . . . "—not to speak of occupational dermatitis and its relationship, if any, to emotional instability, the various aspects of the incidence of accidents, of chronic bronchitis, of the effects of noise, and a host of others. Many contributions have been made on some of these and other subjects, by doctors in industry. The opportunities, the privilege, and the exhilaration of isolating one little iota of truth in the vast welter of surmise, are open to every practitioner of medicine in industry. The factory doctor knows his patients intimately as individuals but he can, if he will, know them too as members of a social group.

There is a separation if not quite a divorce of clinical medicine from social medicine today. It may be that those of us who accept clinical responsibilities (as perforce to some extent we must) and at the same time have the maintenance of the health and welfare of the industrial population while at work, as our duty, will be agents in their reconciliation.

The approach, from an interest in individuals to a concern for coherent groups, has been common to most of our predecessors. To realize that the tradition persists, one has only to think of Henry (1946) whose interest in cancer of the scrotum as a clinical problem led to his study of it as an occupational one—and to its virtual elimination. In more recent years a growing number of men and women have entered our speciality from the opposite direction. With an interest in public health and the behaviour of aggregations of people, they have been led to the industrial field. Their contribution to the techniques of observation and analysis are of the utmost value. Nevertheless occupational medicine remains very largely a clinical subject presenting a wide variety of facets.

It is, unfortunately, true that as in every other branch of the profession there are a few who are so immersed in the routine of the job that they have neither the time nor the inclination to sit back and think of the essential significance of their work. But the work they do is still important. What they miss is the inspiration of knowing that they belong to a group of men and women who are dedicated to the idea that the traditions and the techniques of medicine can contribute immeasurably to the health and happiness of the industrial community. Occupational medicine as a vocation beckons to it technically good doctors, generous in their sympathies, liberal in their sentiments, humble in their ignorance, adventurous in their seeking, and courageous when, as sometimes happens, they are misunderstood by those whom they serve.

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THE RELATIONSHIP BETWEEN VENTILATORY CAPACITY AND SIMPLE PNEUMOCONIOSIS IN COALWORKERS

THE EFFECT OF POPULATION SELECTION

BY

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The diagnosis in life of coalworkers' pneumoconiosis is based on the industrial history and the chest radiograph. The most striking complaint is excessive breathlessness on exertion. The relationship of this symptom to radiological abnormality is of practical importance in assessing compensation; in most schemes the assumption is made that if a readily diagnosable degree of pneumoconiosis is present and the man is breathless, then the breathlessness is caused by the pneumoconiosis if no other cause is apparent. This assumes a reasonably close relationship between radiological abnormality and breathlessness after allowing for the effects of age.

In full reviews of the literature, Worth and Schiller (1954), and Gilson, Hugh-Jones, Oldham, and Meade (1955), conclude that complicated pneumoconiosis is a cause of moderate or severe breathlessness and the extent of the radiological abnormality relates reasonably well to the degree of breathlessness when age is taken into account.

The position in the case of simple pneumoconiosis is far less certain. A number of investigators (Jéquier-Doge and Lob, 1945; Martin and Roche, 1946; Lob, 1947; McVittie, 1949; Theodos, Gordon, Lang, and Motley, 1950; Wright, 1942 and 1946; Gilson, and others, 1955) have found this relationship is not particularly close. At least part of the variability between the findings of different investigators may be ascribed to the effect of bias introduced in the method of selection of the subjects studied. It has, therefore, been our aim to assess the likely magnitude of this effect and obtain a more certain relationship by studying representative groups of miners and ex-miners.

The reproducibility of the radiological diagnosis of coalworkers' pneumoconiosis and the measurement of observer variability have been discussed in previous papers from this Unit (Fletcher and Oldham, 1949 and 1951).

Other aspects of the significance of simple pneumoconiosis in coalworkers' pneumoconiosis have been considered elsewhere: its relation to the development of complicated pneumoconiosis (Fletcher, 1948; Mann, 1951; Cochrane, Davies, and Fletcher, 1951); its relation to life expectancy (Carpenter and Cochrane, 1956); to dust exposure (Roach, 1953), and to dust content in the lungs (King, Maguire, and Nagelschmidt, 1956).

The most direct assessment of breathlessness is by questionnaire, but there are difficulties in its use, particularly in men applying for compensation. Objective measurements, if they are sufficiently highly correlated with the man's principal symptom, have great advantages for studying large and varied groups of subjects. In an evaluation of tests of the main aspects of lung function in miners with pneumoconiosis, Gilson and others (1955) found that ventilatory capacity measured by maximum voluntary ventilation was better related to an independent assessment of breathlessness ($r = 0{\cdot}77$) than any other single test, and only slightly less well correlated than the index obtained by expressing the ventilation on exercise as a percentage of the maximum voluntary ventilation—a test which has been shown by many workers to be reasonably well related to dyspnoea (Cournand and Richards, 1941; Wright, 1942; Warring, 1949). The physiological tests were more sensitive than the clinical assessments.

The maximum voluntary ventilation is a simple test, but it takes longer and causes rather more discomfort to the subject than measuring the ventilatory capacity by a single forced expiration. A number of studies of the relationship between the maximum voluntary ventilation and the volume expelled during the first part of a forced expiration (Roche and Thivollet, 1949; Tiffeneau, Bousser, and Drutel, 1949; Kennedy, 1953; McKerrow, 1955; Bernstein and Kazantzis, 1954; Leuallen and Fowler, 1955) have in general shown a high correlation between the two. Direct comparison of both tests, and a study of the relation of the results of the single breath method with the clinical grading of dyspnoea

have led us to choose the single breath method on account of its simplicity, slightly better repeatability, and very small observer error under field survey conditions (Carpenter and others, to be published). Even though the physiological assessment may not be an ideal measure of breathlessness, we believe it gives more valid information about the prevalence of respiratory disability than could be obtained by questionnaire alone.

POPULATION GROUPS

In the prevalence type of survey, the following groups of miners can be examined:

(1) Patients in hospital.

(2) Men attending for compensation assessment at the Pneumoconiosis Medical Panel.

(3) Miners working in a colliery
  (i) underground workers only
  (ii) surface workers only
  (iii) both surface and underground workers.

(4) Miners and ex-miners from a geographically defined area.

Patients in hospital are a highly selected group and tend to be biased towards those who are disabled. They are admitted for two main reasons: a minority for diagnostic or physiological investigation, and the majority because of an exacerbation of acute respiratory infection or the onset of congestive heart failure. They are, therefore, quite unsuitable for our present purpose and are not considered in this paper.

Miners attending for compensation may also be a biased group. Those most likely to apply for compensation are either the disabled or men in whom radiological abnormality has been detected (for example, during mass miniature radiological surveys). In addition miners who are " compensation minded" may also attend though they feel fit. The results on examining such a group will depend on the proportions of each class in the population.

A working population at a colliery is likely to be more representative but is not ideal because it excludes those who have left the industry. As respiratory disability is in some areas an important cause of a man giving up mining, the exclusion of ex-miners may introduce a serious bias into the results. Restriction to a group working underground or on the surface cannot be recommended, since miners too disabled to work underground are often given lighter employment on the surface (McCallum and Browne, 1955).

A community of miners and ex-miners within a geographically defined area is in our view the group in which bias is least likely to occur, and, provided the area is not too large, it is a practical group to study. Differential death rates within the group may still upset the results but in the cases of simple pneumoconiosis this is not likely to be important (Carpenter and Cochrane, 1956). The results may not apply to miners and ex-miners in all areas on account of regional differences including climate, overcrowding, type of mining, and the extent of emigration from the area, so there is need to study several mining communities.

In the present paper, after considering the effect of age on ventilatory capacity, we describe the results of studies in groups of miners applying for compensation and of a working pit population, and then of three random samples of miners and ex-miners, two of the samples drawn from the population of the Rhondda Fach (a mining valley in South Wales) and one from the town of Leigh in Lancashire.

METHODS

Radiological

Full-size chest films were obtained for all subjects. The films were classified on the I.L.O. International Classification (1950) grading (Cochrane and others, 1951; Fletcher, 1955) into four groups: category 0—no evidence of pneumoconiosis; category 1, a few characteristic opacities 0·5-3 mm. in diameter in at least two rib spaces and extending over 1 sq. cm. or more; category 2, more numerous opacities distributed throughout the lung field; category 3, profuse opacities throughout both lung fields.

In order to minimize errors of classification the films were read by four observers working in pairs. Each pair read the films separately. Those films about which there was a difference of opinion were then reviewed by all four observers in consultation and an agreed reading decided. Standard films were used in cases of doubt.

Ventilatory Capacity Test: Maximum Voluntary Ventilation (Indirect) M.V.V.

The ventilatory capacity was measured by recording the volume of gas expelled during the first 0·75 second of a forced expiration starting from maximum inspiration using a modified Gaensler (1951) apparatus. (The timing started after 100 ml. had been expelled; this makes some allowance for variations in the abruptness of the start of expiration.)

The first reading was rejected and the mean of three or four subsequent readings (corrected to B.T.P.S.) was taken. The results have been expressed in l./min. by multiplying by 40 in the way suggested by Kennedy (1953), but we have followed Tiffeneau's terminology by referring to the measurement as maximum voluntary ventilation (indirect) in place of the expiratory flow rate ($E.F.R._{40}$) used by Kennedy. In the population samples including miners and others the observers were unaware of the subjects' occupations.*

* Sitting height, which is correlated with M.V.V. (indirect) (1 in. being equivalent to 6·8 l./min.) was measured to the nearest 0·5 in. Correction of our results for the small differences in average sitting height of our groups did not affect our findings and was, therefore, omitted.

RESULTS

Effect of Age on the Ventilatory Capacity

The effect of age on the ventilatory capacity is so striking that full allowance for age is essential. Fig. 1 and Table 1 show the decline in the maximum voluntary ventilation (indirect) with increasing age in a non-mining male population aged 20-69 years examined in the first Rhondda Fach study. The mean M.V.V. values are plotted against the mean age of the group. The regression of M.V.V. on age was 1·36±0·141 l./min. for each year, and testing the means of the five-year age groups showed no evidence that the relationship (within this age range) is non-linear ($0{\cdot}2 > P > 0{\cdot}1$).

The rate of decline with age agrees well with that reported for the two-second timed vital capacity by Needham, Rogan, and MacDonald (1954).

FIG. 1.—Relation of age to maximum voluntary ventilation (indirect) in a random sample of non-miners living in the Rhondda Fach.

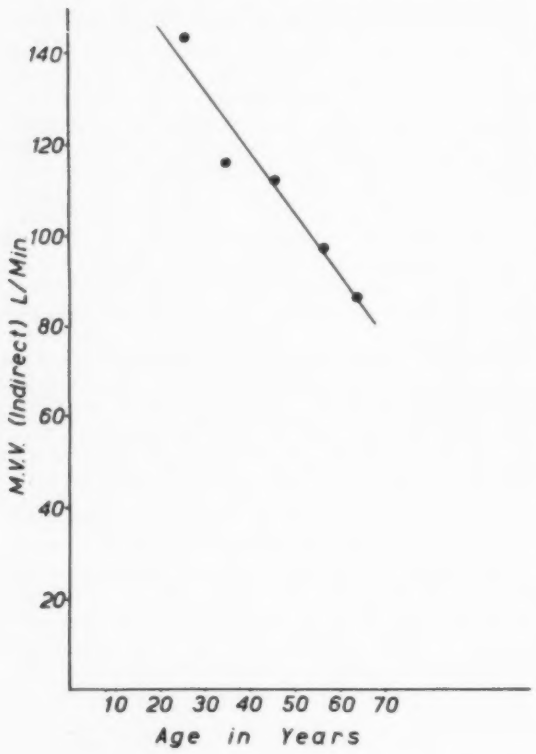


TABLE 1

EFFECT OF AGE ON M.V.V. (INDIRECT) IN A RANDOM SAMPLE OF NON-MINERS FROM THE RHONDDA FACH

Age Group	No. Tested	Mean Age (years)	Mean M.V.V. (l./min.)
20–	20	24·8	143·6
30–	19	34·0	116·3
40–	19	44·8	112·2
50–	31	55·6	97·3
60–	34	63·1	86·8

Regression of M.V.V. on age is − 1·36 ± 0·141 l./min. for each year
S.D. of M.V.V. of one subject about regression line is 22·5 l./min.

Relation between Radiological Category and Ventilatory Capacity

Compensation Group.—Three hundred and twenty-seven miners and ex-miners attended the Pneumoconiosis Medical Panel in Cardiff between February 16, 1953, and February 26, 1953. Of these, 316 (96·6%) were examined and 11 (3·4%) refused to cooperate. Men with progressive massive fibrosis (P.M.F.) were excluded and the average M.V.V. for the 204 men remaining aged 25-64 by 10-year groups are given in Fig. 2 and Table 2. There is a general trend for the M.V.V. to *rise* with category of simple pneumoconiosis. This unexpected result could be due either to the effect of selection or to a real trend in this direction. It was impossible to say which of these two explanations was correct. This survey showed the need for further study.

Working Miners (Colliery L).—A radiographic survey of all miners in a Lancashire colliery was carried out; of the total population, the following groups were studied:—

(1) All miners over the age of 40; (2) all miners under the age of 40 whose radiographs showed pneumoconiosis; (3) a random sample of miners under 40 with normal radiographs. Of the whole group 87% were seen, giving a lapse rate of 13%.

The results of the M.V.V. for men aged 25-64 in 10-year groups are shown in Fig. 3 and Table 3. These show that there was in the main a *fall* in the mean ventilatory capacity with increasing category of simple pneumoconiosis. When all age groups are taken together the fall in M.V.V. is 5·25±1·73 l./min. with each radiological category, and is significant ($0{\cdot}01 > P > 0{\cdot}001$). In the 55-64 age group, though the numbers were small, miners with categories 1 and 2 simple pneumoconiosis recorded a higher average M.V.V. than those without pneumoconiosis.

The results of this survey were those that common sense would have predicted. They do, however, conflict strikingly with the results in the compensation group. This is well seen in Fig. 4 which shows the mean values of all the men examined in both surveys standardized to an arbitrary age of 45 years. (This standardization is justified because the effects of increasing radiological category are reasonably similar at different ages.)

The population studied was, we thought, a good

FIG. 2.—Relation of age and radiological category of simple pneumoconiosis to maximum voluntary ventilation (indirect) in compensation group of miners and ex-miners.

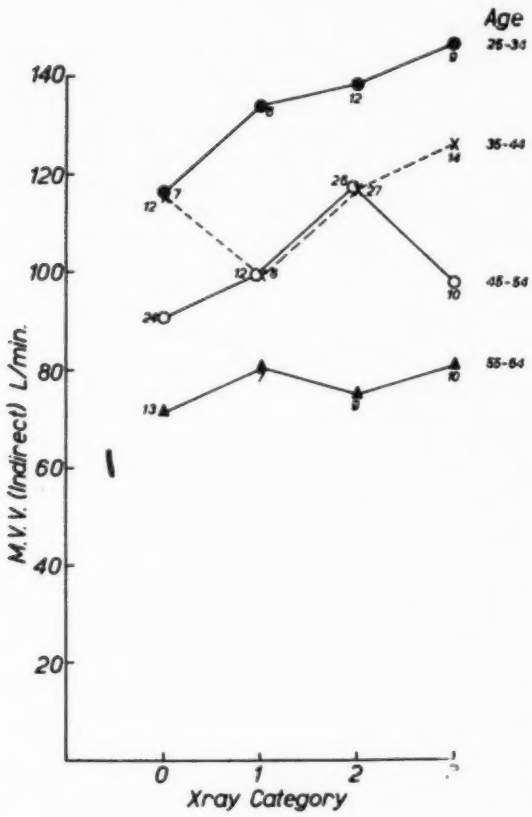


FIG. 3.—Relation of age and radiological category of simple pneumoconiosis to maximum voluntary ventilation (indirect) in a sample of miners working in Colliery L.

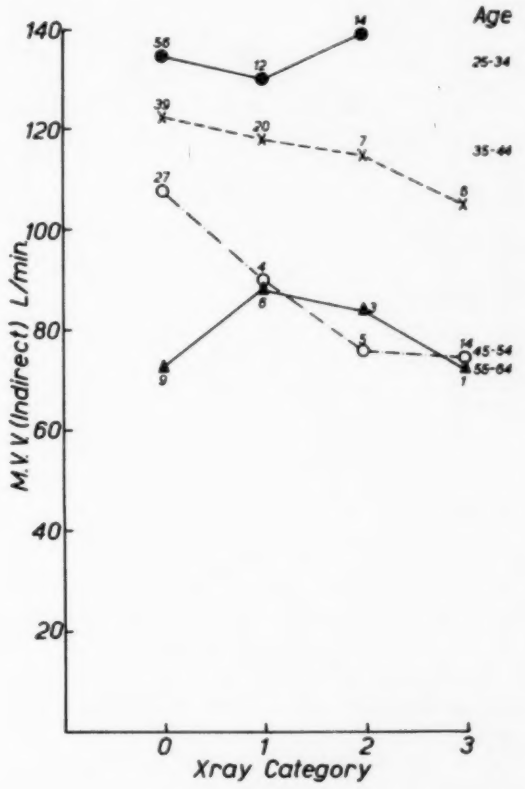


TABLE 2

MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO RADIOLOGICAL CATEGORY IN A COMPENSATION GROUP OF MINERS AND EX-MINERS AGED 25-64 YEARS

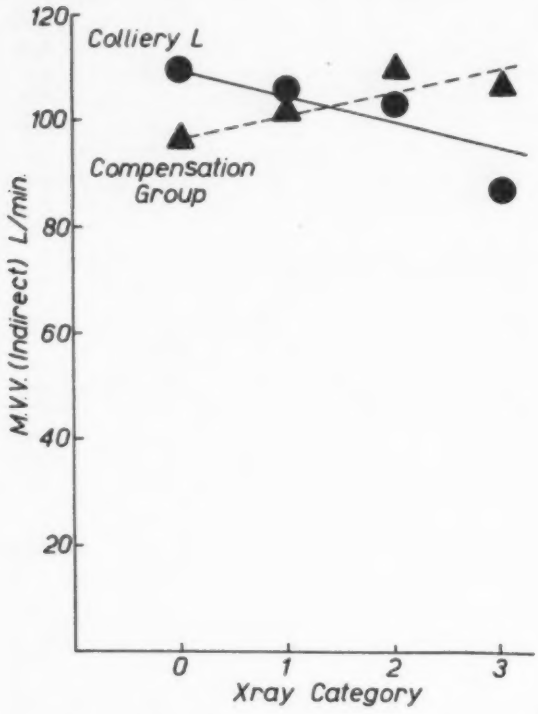
Age Group	Radiological Category	Number	Mean Age	Mean M.V.V.
25–	0	7	29·9	116·3
	1	6	30·8	133·8
	2	12	30·3	138·3
	3	9	29·8	147·0
35–	0	12	39·2	115·4
	1	6	40·6	99·5
	2	27	40·0	116·7
	3	14	38·2	126·1
45–	0	24	49·2	90·9
	1	12	48·2	99·4
	2	26	48·1	117·6
	3	10	48·2	98·3
55–	0	13	60·5	71·3
	1	7	58·6	80·6
	2	9	59·8	75·3
	3	10	59·9	81·4

TABLE 3

MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO RADIOLOGICAL CATEGORY IN A SAMPLE OF WORKING MINERS AGED 25-64 YEARS AT COLLIERY L

Age Group	Radiological Category	Number	Mean Age	Mean M.V.V.
25–	0	56	29·2	134·5
	1	12	30·4	129·9
	2	14	29·4	138·6
	3	0	—	—
35–	0	39	39·1	122·3
	1	20	40·0	117·6
	2	7	37·6	114·6
	3	6	40·5	104·7
45–	0	27	47·5	107·7
	1	4	47·0	89·8
	2	5	48·4	75·8
	3	14	49·1	74·2
55–	0	9	59·1	72·1
	1	6	58·2	88·2
	2	3	55·7	83·7
	3	1	61·0	72·0

FIG. 4.—Relation of radiological category of simple pneumoconiosis to age standardized maximum voluntary ventilation in Colliery L and the compensation groups. (M.V.Vs. are standardized to age 45.)



one of working miners and the results were considered to be more likely to be correct than those found in the compensation group. The findings in the compensation group could not, however, be ignored and a further survey was designed to find out which of the previous two investigations, if either represented the true picture.

Random Sample of Radiographed Population of the Rhondda Fach.—We considered (wrongly as it turned out) that the effect of simple pneumoconiosis on the ventilatory capacity would best be shown by considering radiological extremes. Two main groups of miners and ex-miners were, therefore, examined: those without pneumoconiosis (category 0) and those with advanced simple pneumoconiosis (category 3). Men from these two groups were sampled in each of two age groups, 25-34 and 55-64 years. Comparable groups of non-miners were also studied. This sampling on the basis of known radiological reading was possible since 90% of the population (about 30,000) of the valley had been recently radiographed (Cochrane, Cox, and Jarman, 1955).

One hundred and twenty-four (95%) of the 130 non-miners and 187 (94%) of the 199 miners and ex-miners drawn in the sample from the radiographed population were seen. The overall lapse rate was, therefore, 5% of the radiographed population. Seventy-two of the non-miners were in age groups comparable with the miners and ex-miners. The remaining 52 gave the additional data to establish the relationship of M.V.V. (indirect) to age.

The results are shown in Fig. 5 and Table 4. In each age group miners recorded a lower ventilatory capacity than non-miners. The difference of 11·5 l./min. between the mean M.V.V. of the non-miners and the miners and ex-miners without pneumoconiosis aged 25-34 years is significant at the 5% level ($0{\cdot}05 > P > 0{\cdot}01$); that of 24·4 l./min. between the groups aged 55-64 is highly significant ($P < 0{\cdot}001$). Little difference was observed between the men with category 0 and category 3 simple pneumoconiosis in the younger age group. In the older men, however, those with pneumoconiosis

FIG. 5.—Relation of age, occupation, and radiological category of simple pneumoconiosis to maximum voluntary ventilation (indirect) in first random sample from the Rhondda Fach. (NM = non-miners.)

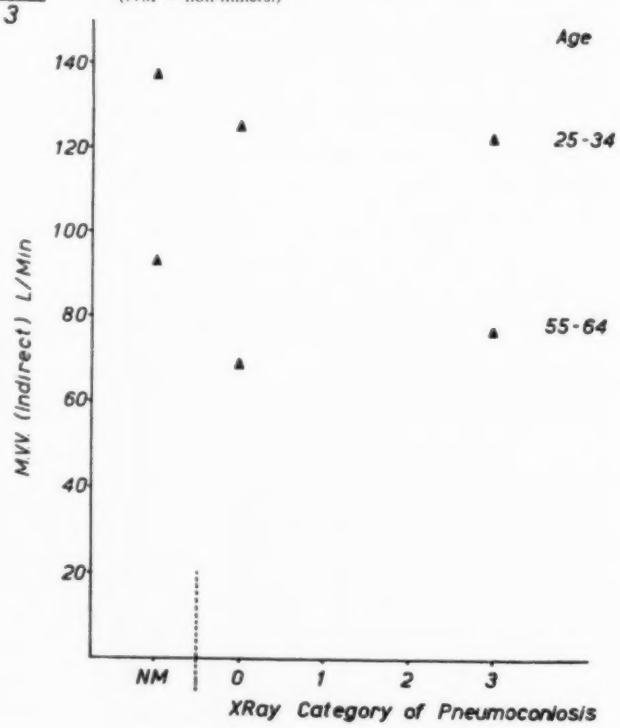


TABLE 4

MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO OCCUPATION AND RADIOLOGICAL CATEGORY IN A RANDOM SAMPLE OF THE RADIOGRAPHED POPULATION OF THE RHONDDA FACH AGED 25-34 AND 55-64 YEARS

Age Group	Occupation	Radiological Category	No.	Mean Age	Mean M.V.V.	S.E. of Mean M.V.V.
25–34	Non-miners	—	22	28·9	137·2	±4·06
	Miners and ex-miners	0	47	31·1	125·7	±2·78
		3	47	31·0	122·2	±2·78
55–64	Non-miners	–	50	59·6	92·9	±3·54
	Miners and ex-miners	0	47	59·7	68·5	±3·66
		3	46	59·6	77·1	±3·69

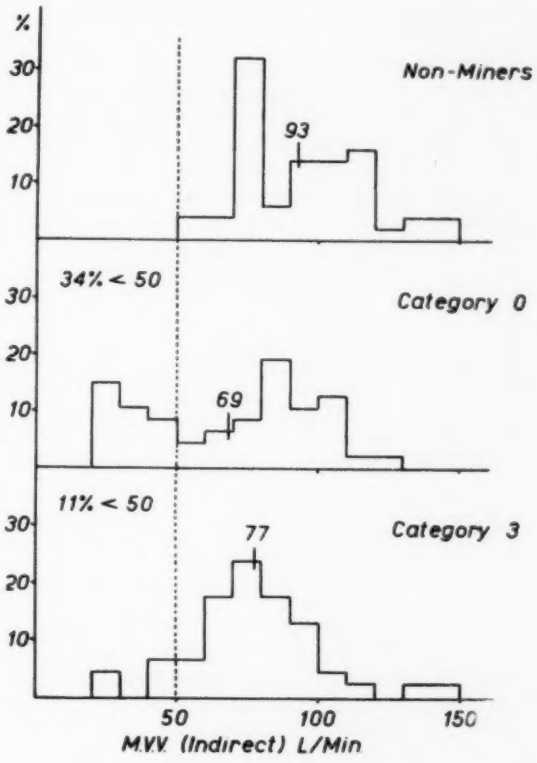
had a higher average M.V.V. than those without (77·1 compared with 68·5 l./min.), but the difference is not quite statistically significant. The standard deviation of the M.V.V. is 19·0 l./min. in the 25-34 and 24·1 l./min. in the 55-64 age groups.

The clinical significance of a reduction in M.V.V. is very different at opposite ends of its range. A fall from 140 to 120 l./min. is unlikely to be noticed except on very severe exertion, whereas a fall from 60 to 40 l./min. is likely to be associated with a noticeable increase of breathlessness on slight exertion. When the value falls to 50 l./min. and below a material limitation of activity on account of dyspnoea is to be expected.

The choice of 50 l./min. is based on evidence on the relationship of dyspnoea to exercise ventilation (E.V.) and M.V.V. In our previous report it was shown that a dyspnoeic index ($\frac{\text{E.V.}}{\text{M.V.V.}} \times 100$) of 50% corresponded to an average clinical assessment of breathlessness between grades 2 and 3 (Gilson and others, 1955). Seventy per cent of men with an M.V.V. (direct) of 50 l./min. or less (17 subjects) did not complete five minutes of moderate stepping exercise standardized at 350 kg./m./min., whereas only 6% of those with an M.V.V. greater than 50 l./min. (140 subjects) failed to do so. Also Cournand and Richards (1941) showed that when the breathing reserve (M.V.V.—E.V.) fell to 60 to 70% of the M.V.V., dyspnoea was usually present. Thus exertion which produces an average ventilation of 25 l./min. will cause definite dyspnoea in the majority of those with an M.V.V. of 50 l./min.

Frequency distributions of the ventilatory capacity measurements in the 55-64 age group are given in Fig. 6. None of the non-miners, but 10·9% of the miners with category 3 and 34·0% of miners without pneumoconiosis recorded an M.V.V. of under 50 l./min. The excessive proportion of those with an M.V.V. of 50 l./min. and below among the miners without pneumoconiosis is striking and when tested

FIG. 6.—Histograms of the distribution of maximum voluntary ventilation (indirect) for non-miners, miners, and ex-miners, aged 55-64, categories 0-3, in a random sample from the radiographed population of the Rhondda Fach.



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We have had an opportunity of studying the intermediate groups, namely categories 1 and 2 simple pneumoconiosis, in two subsequent surveys.

Second Random Sample of Miners and Ex-miners from the Rhondda Fach.—A private census of the valley was carried out in March, 1953, at the time of the second radiological survey (Cochrane and others, 1955). From this census a sample of 55 miners and ex-miners aged 55-64 was drawn in May, 1954. Of the 55, two had died, two had left the area, and four refused to cooperate. The remaining 47, 85·5% of the sample or 92·2% of

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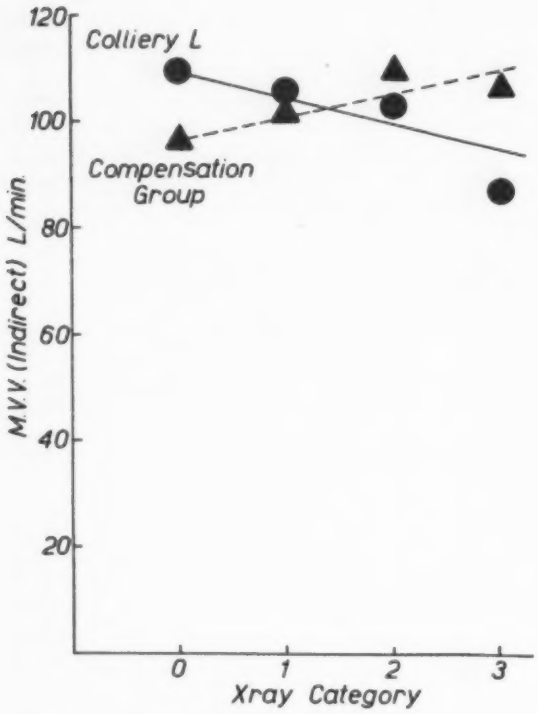

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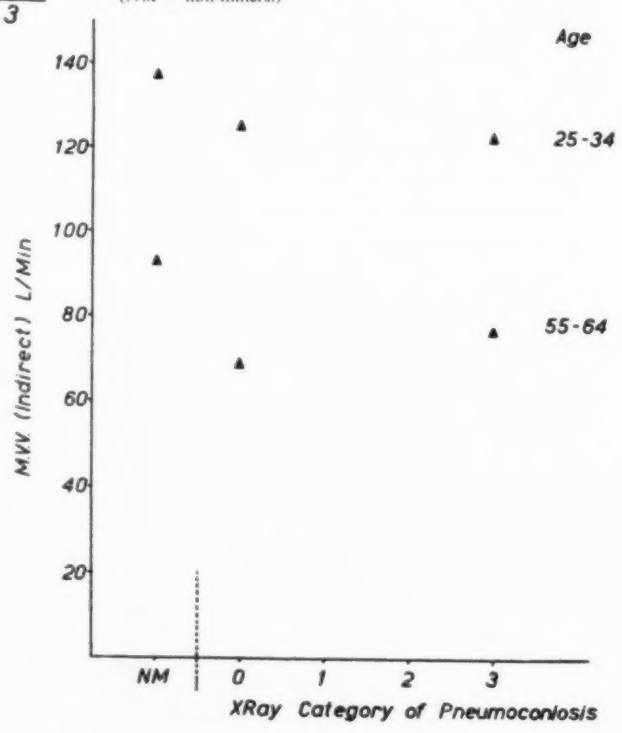

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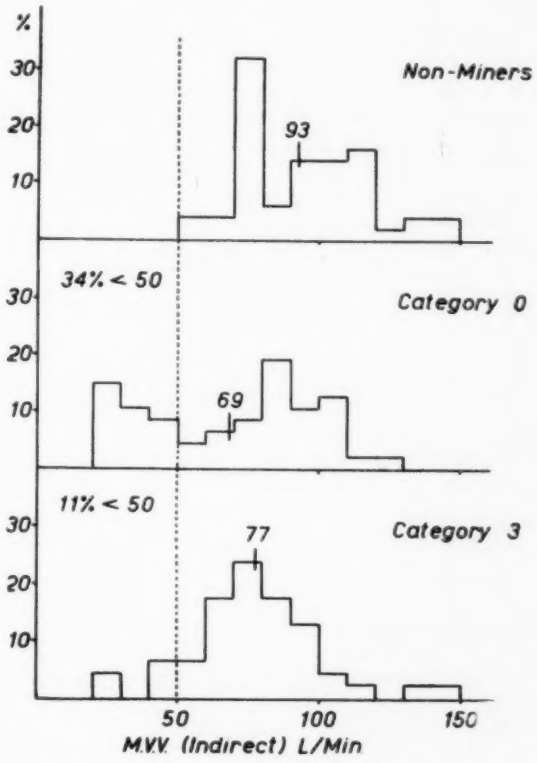

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FIG. 7.—Relation of occupation and radiological category of simple pneumoconiosis to maximum voluntary ventilation (indirect) in men aged 55-64 in two random samples from the Rhondda Fach and one from Leigh.

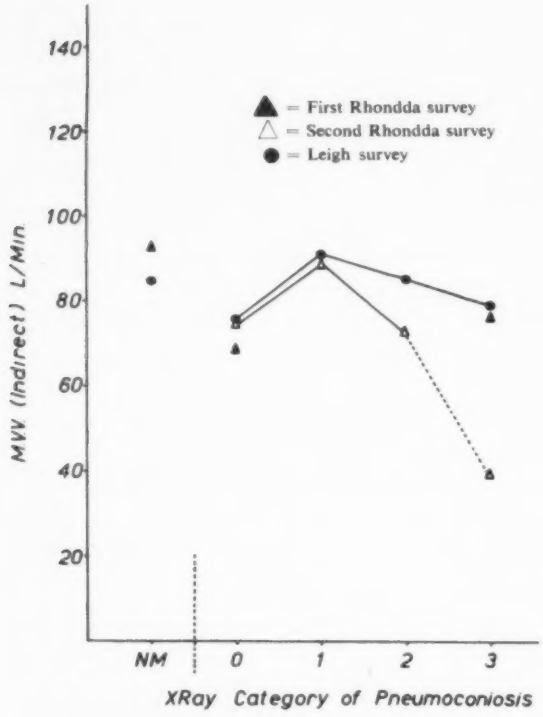


TABLE 5

MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO RADIOLOGICAL CATEGORY IN SECOND RANDOM SAMPLE OF MINERS AND EX-MINERS AGED 55-64 YEARS FROM THE RHONDDA FACH

Age Group	Radiological Category	Number	Mean Age	Mean M.V.V.	S.E. of Mean M.V.V.
55–64	0	19	60·6	75·1	±5·43
	1	6	60·0	89·2	±9·67
	2	10	58·9	73·1	±7·49
	3	1	64·0	40·0	±23·67

those still living in the valley, were examined (Thomas, Cotes, and Higgins, 1956). The results of the M.V.V. related to radiological category (excluding 11 with P.M.F.) are shown in Fig. 7 and Table 5. These results will be discussed with those of the next survey.

Random Sample of Miners and Ex-miners and Non-miners of Leigh, Lancashire.—In November, 1954, a sample of 245 men aged 55-64 was obtained by selecting houses at random from the electoral rolls, visiting the houses so drawn and inviting any man aged 55-64 living in them to cooperate with us in our investigation. Details of this sampling technique in Leigh will be published elsewhere (Higgins, Oldham, Cochrane, and Gilson, 1956).

Of the 245 men in the sample, 146 were miners or ex-miners who had had one or more years of mining, and of these 135 (92·5%) were examined. Of the 99 who had never worked in mines 86 (86·9%) were examined. Twenty-one miners and ex-miners had P.M.F. Three miners and ex-miners and two non-miners had significant respiratory disease other than emphysema or simple pneumoconiosis. The results of the M.V.V., after exclusion of these men, are shown in Fig. 7 and Table 6. There is good agreement between the mean M.V.V. for the miners and ex-miners who had category 0 and category 1 simple pneumoconiosis respectively in the Rhondda and Leigh. In both areas the men aged 55-64 with early simple pneumoconiosis (category 1) recorded a higher mean M.V.V. than those without evidence of pneumoconiosis. The agreement in the case of the men with category 2 simple pneumoconiosis is less good. Since there was only one man in the second Rhondda Fach sample with category 3 pneumoconiosis this category cannot be compared.

TABLE 6

MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO OCCUPATION AND RADIOLOGICAL CATEGORY IN RANDOM SAMPLE OF MEN AGED 55-64 EXAMINED IN LEIGH

Age Group	Occupation	Radiological Category	No.	Mean Age	Mean M.V.V.	S.E. of Mean M.V.V.
55–64	Non-miners	–	84	59·4	85·0	±2·53
	Miners and ex-miners	0	101	59·1	76·0	±2·30
		1	6	57·3	91·5	±9·45
		2	7	59·0	86·0	±8·75
		3	8	58·8	79·8	±8·18

At Leigh 7% of the non-miners and 17% of the miners and ex-miners with category 0 recorded an M.V.V. of less than 50 l./min.

The results of these two samples of complete populations may be compared with those obtained for the men aged 55-64 with category 0 and category 3 simple pneumoconiosis from the sample of the radiographed population in the Rhondda Fach. Fig. 7 shows that for the men with category 3 the agreement is remarkably close between the first Rhondda Fach and Leigh samples—a difference of only 2·8 l./min. In the case of the miners without pneumoconiosis the agreement is not quite so close. The mean for the Rhondda sample was 7·5 litres lower than for that in Leigh but the difference is not statistically significant.

Combined Results in Three Random Samples.—The results in these three random samples are, however, sufficiently similar to justify pooling them in order to

FIG. 8.—Relation of occupation and radiological category of simple pneumoconiosis and "bronchitis" to maximum voluntary ventilation (indirect) in the three random samples combined (age 55-64).

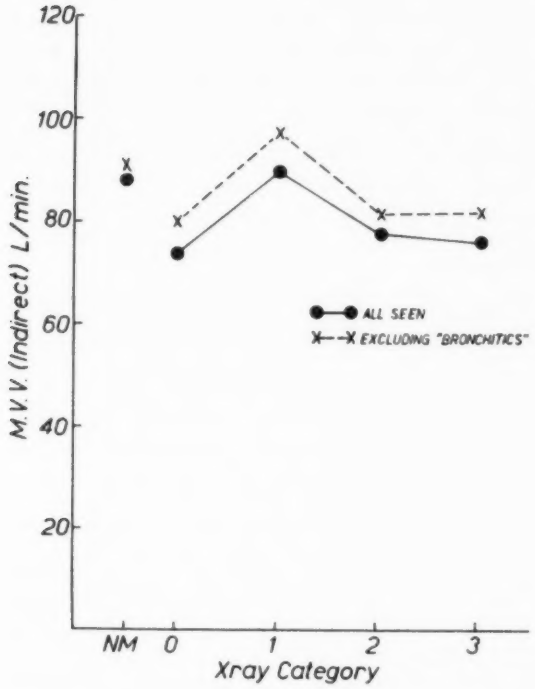


TABLE 7

MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO OCCUPATION AND RADIOLOGICAL CATEGORY IN THREE RANDOM SAMPLES COMBINED (NON-MINERS, MINERS, AND EX-MINERS AGED 55-64 YEARS)

Age Group	Occupation	Radiological Category	Number	Mean Age	Mean M.V.V.
55–64	Non-miners	–	134	59·5	88·0
	Miners and ex-miners	0	167	59·5	73·8
		1	12	58·7	90·3
		2	17	58·9	78·4
		3	55	59·5	76·8

obtain the best measure of the true relation between radiological category of simple pneumoconiosis and ventilatory capacity in the age group 55-64. This has been done in Fig. 8 and Table 7. A representative sample of non-miners of the same age from the same geographical areas was studied at Leigh and in the Rhondda. The mean M.V.V. in this group has also been included.

The characteristics of the curve are that the miners and ex-miners without pneumoconiosis record a lower mean M.V.V. than non-miners and that those with category 1 simple pneumoconiosis a *higher* value than those with category 0. Those with categories 2 and 3 simple pneumoconiosis have lower values than those with category 1. It is well recognized that other respiratory diseases, notably bronchitis and emphysema, often cause a reduction in the ventilatory capacity (Cournand, Richards, and Darling, 1939; Wright, 1946; Lavenne and Belayew, 1953; Foubert, Nadiras, and Batique's, 1954). In the three random samples studied, respiratory symptoms were recorded using a questionnaire. Those men who had had a chest illness with cough and sputum during the past three years, and also persistent cough and/or sputum were considered for the purposes of this study to have "bronchitis". The mean ventilatory capacities in each group, excluding these "bronchitics", are given in Table 8 and are indicated in Fig. 8 by the interrupted line. It will be seen that the exclusion of "bronchitics" does not affect the shape of the ventilatory capacity/radiological category curve, although for the first Rhondda Fach sample alone removing the "bronchitics" did bring the mean M.V.V. for those with categories 0 and 3 nearer together. The observation that in the older age group men without pneumoconiosis have a lower ventilatory capacity than men with category 1 simple pneumoconiosis is a consistent one throughout our surveys. Table 9 shows the mean values for the two groups in six investigations.

TABLE 8

MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO OCCUPATION AND RADIOLOGICAL CATEGORY IN THREE RANDOM SAMPLES COMBINED, EXCLUDING "BRONCHITIC" (NON-MINERS, MINERS, AND EX-MINERS AGED 55-64 YEARS)

Age Group	Occupation	Radiological Category	Number	Mean Age	Mean M.V.V.
55–64	Non-miners	–	115	59·3	91·2
	Miners and ex-miners	0	121	59·4	78·8
		1	8	58·8	97·9
		2	14	59·5	82·1
		3	33	59·3	81·9

It is important to bear in mind the wide scatter of values of the M.V.V. that are recorded in each of the groups. Fig. 9 shows the mean and scatter

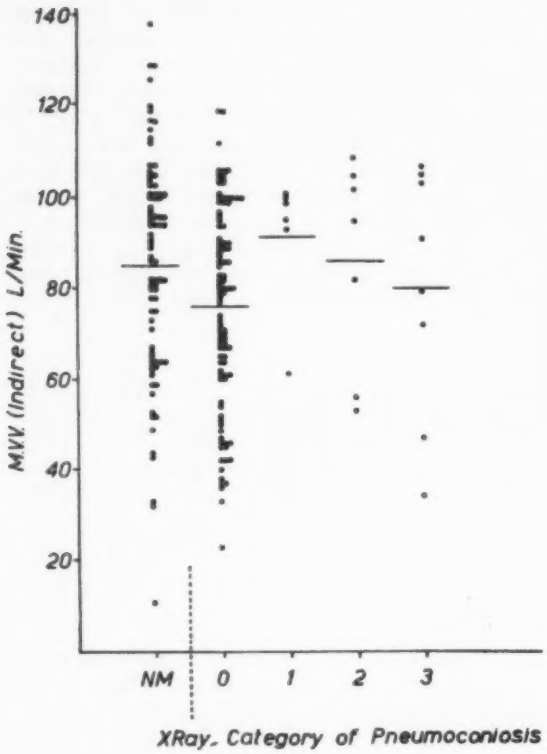
TABLE 9

VENTILATORY CAPACITY IN CATEGORY 0 AND MEAN CATEGORY 1 SIMPLE PNEUMOCONIOSIS IN SAMPLES OF ELDERLY MINERS AND EX-MINERS

	Sample	Category 0		Category 1	
M.V.V. (indirect) Age 55-64	Compensation group	71	(13)*	81	(7)
	Colliery L	72	(9)	88	(6)
	Rhondda Fach	75	(19)	89	(6)
	Leigh (Lancs.)	76	(101)	92	(6)
M.V.V.† (direct) Age 50-59	Main experiment	94	(8)	100	(8)
	Colliery B	80	(23)	92	(23)

*Numbers in each sample.
†Gilson and others (1955)

FIG. 9.—Relation of occupation and radiological category of simple pneumoconiosis to maximum voluntary ventilation (indirect) in a random sample from Leigh (age 55-64).



in the random sample of the population in Leigh. This shows that men with severe limitation of ventilatory capacity, and, by implication, a marked degree of breathlessness, will be found in all radiological categories, and that only a small proportion of their disability is related to the extent of their pneumoconiosis as described by their radiological category.

Discussion

The conflicting results for the compensation and working miner groups show clearly how the method of selection can influence investigations of this kind. By studying random samples from geographically defined populations and only having a small refusal rate, we believe we have established the relationship between the category of simple pneumoconiosis and ventilatory capacity with much greater certainty than was previously known.

Our earlier findings (Gilson and others, 1955) that miners with and without simple pneumoconiosis have a lower average maximum voluntary ventilation than men of the same age who have never worked at mining is confirmed. Also the observation that elderly working miners without radiological evidence of pneumoconiosis have a slightly lower average M.V.V. (p. 129) than miners with category 3 simple pneumoconiosis has been shown to apply to random samples of miners and ex-miners.

The review of the literature up to 1953 (Gilson and others, 1955) revealed how unrepresentative were the groups of subjects studied by most workers in attempting to relate radiological category to lung function study in pneumoconiosis. Worth and Schiller (1954) in another review have also shown the conflicting results reported by different workers. Recently Foubert and others (1954) reported the results of applying spirometry at rest to 1,500 miners. They observed no important change of ventilatory capacity with simple pneumoconiosis and stressed the importance of other factors causing disability. Direct comparison with our findings is, however, not possible as their results are all expressed in terms of percentages of predicted values. Lavenne and Belayew (1953) studied a group of 205 working miners more comparable with ours at Colliery L. They found no change of ventilatory capacity with the degree of simple pneumoconiosis. They comment that their findings are probably influenced by selection, the more disabled men having left the mine. Newell and Browne (1955) in a study of 5,117 working miners were unable to show any relationships between radiological category of pneumoconiosis and respiratory disability estimated from symptoms and change of job.

Our findings raise a number of points to which definite answers cannot yet be given. For example, why should miners have a low average ventilatory capacity and why should those with normal films in the age group 55-64 be more affected than those with early simple pneumoconiosis ?

It is possible that one or more of such factors as occupational selection, nutrition, housing, and medical care might be the cause of the difference between the miners and those without mining experience. We doubt if the main cause is to be found in these factors. By making comparisons with non-miners living in the same area we have to some extent compensated for the effects of housing and medical care. Also in Leigh the observed differences in respiratory symptoms in the miners and non-miners could not be accounted for by differences in social class (as defined by the Registrar General) or by differences in the amount of tobacco smoked (Higgins and others, 1956). It seems more probable that mining itself is responsible either as a result of pollution of the atmosphere by dust and fumes, or on account of the type and severity of physical exertion required. An attempt to assess the

importance of some of these factors is now being made by making a comparison with agricultural workers (Cochrane and others, 1956).

The unexpected finding of a higher ventilatory capacity in men with early simple pneumoconiosis than those with normal films might be attributed in part to occupational self-selection: the men with higher ventilatory capacity being capable of greater activity without dyspnoea might be more likely to work on the coal-face and so receive a heavier dust exposure. Our findings do not support this view. At Leigh in the age group 55-64 the mean years on the coal-getting shift of those with category 1 was 5·5 compared with 11·3 years for those with category 0. The differences are not solely due to an increased prevalence of respiratory infection in those with normal radiographs since it is still seen after removing the cases of " bronchitis ".

In the miners and ex-miners without pneumoconiosis aged 55-64 the low average M.V.V. and its biphasic distribution might be adduced as evidence that this group was not homogeneous, but consisted of those men with a typical distribution of M.V.V. for their age, with the addition of others selected on the basis of a low M.V.V. It is possible that this may be so for it may include men who had early pneumoconiosis (category 1 and early category 2) in whom the development of emphysema has obscured the dust. If this hypothesis is correct it should be possible to detect a radiological regression of early simple pneumoconiosis in the elderly. In our experience regression of well established simple pneumoconiosis is rare; but a special study in elderly miners with early simple pneumoconiosis has not yet been possible. A follow-up over 10 years between the ages of 50 and 60 would be required. Pathologists have stressed the importance of focal emphysema as a cause of disability (Heppleston, 1953; Gough and Heppleston, 1955). As the condition cannot yet be diagnosed in life (except by biopsy) we are unable to state its significance in relation to our observations.

On the other hand, generalized emphysema of the usual types could account for our findings, but it would be unjustifiable to ascribe the reduced ventilatory capacity to this alone on the basis of a single test of lung function. In addition the lowered ventilatory capacity in the miners aged 25-34 (when emphysema is rare) compared with the normals suggests that other changes may also be occurring. The fall in ventilatory capacity is not caused by a decrease in expiratory muscle force since the maximum static pressure which could be sustained was not significantly related to the M.V.V. in the miners in the Rhondda Fach. There was a significant correlation ($r = 0{\cdot}69$) between the M.V.V. and airways resistance of the lungs (McDermott, personal communication).

Our results do not support the hypothesis that the reduced ventilatory capacity is directly related to the severity of dust exposure. The men with category 3 simple pneumoconiosis had spent about twice as long on the coal-face as those with category 0, and within the category 3 group aged 55-64 in the Rhondda Fach there was no relation between M.V.V. and years on the coal-getting shift. In the miners with category 0 both in Leigh and in the Rhondda there was only a weak relationship between years on the coal-getting shift and a decreased M.V.V.

It seems possible that mining does in some ways accelerate, to a marked extent in some individuals, the normal decline in ventilatory capacity which occurs with age. The fall of M.V.V. with each radiological category of simple pneumoconiosis was 6 litres in the Leigh sample and 5·2 litres in the working miners in Colliery L. The regression of M.V.V. on age was 1·4 l./min. for each year of life in the first sample studied in the Rhondda Fach, thus each radiological category of simple pneumoconiosis is about equivalent to four years of life in its effect on ventilatory capacity. What this process is will perhaps be better understood when the underlying changes causing emphysema are elucidated.

Summary

The relation of radiological category of simple pneumoconiosis (I.L.O. Classification, 1950) to ventilatory capacity measured by the volume expelled during the first 0·75 second of a forced expiration (M.V.V. indirect) has been studied in several groups: (i) miners applying for compensation (204); (ii) working miners (223); (iii) randomly selected miners and ex-miners, and non-miners from two communities (553).

The results in the first two investigations were contradictory, indicating the need to study representative groups of miners and ex-miners. In the three random samples the results were concordant.

A linear fall of 1·36 l./min. in M.V.V. for each year of life was observed in non-miners aged 20-69 years.

In the age group 55-64 the miners and ex-miners without pneumoconiosis had a lower average M.V.V. than those with simple pneumoconiosis categories 1 and 2 and about the same as the miners with category 3.

The unexpected relationship is still observed after excluding subjects with " bronchitis "; possible reasons are discussed.

From a study of the proportion of miners and

non-miners with an M.V.V. of 50 l./min. or less in the age group 55-64 it is concluded that respiratory disability of a moderate or severe degree is commonest in miners with category 0 and category 3 films, and also that the proportion among miners is higher than in non-miners in the two communities studied.

We should like to express our thanks to the men in the Rhondda Fach and in Leigh for their willing cooperation; to the staff of the National Coal Board and the members of the National Union of Mineworkers at the Colliery; and to Dr. R. W. Thomas and the staff of the Cardiff Pneumoconiosis Medical Panel.

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FACTORS INFLUENCING THE RADIOLOGICAL PROGRESSION RATE OF PROGRESSIVE MASSIVE FIBROSIS

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The Workmen's Compensation (Silicosis) Act (1918) empowered the Secretary of State to make (*inter alia*) schemes "for the payment of compensation to workmen who are found on medical examination to be suffering from silicosis or silicosis combined with tuberculosis to such a degree as to make it dangerous to continue work in the industry and are for that reason suspended from employment". The idea that when a certain stage of silicosis has been reached it becomes dangerous to continue at work appears to have its origin in the Miners' Phthisis Act (1912) in the Union of South Africa, but neither in 1912 nor in 1918 does there appear to have been any detailed discussion of the stage at which it became more dangerous to continue at work than to leave it: or, to put the problem in more epidemiological terms, the stage after which the progression rate, *i.e.*, deterioration rate, was higher at work in the mines than outside.

Coal-mining was not included in the list of industries scheduled in the original scheme (Refractory Industries (Silicosis) Scheme, 1919) but was added in 1928 (Various Industries (Silicosis) Scheme). Even then, owing to the phrase "exposure to silica dust" in the Act, few coal-miners were certified until the Coal Mining Industry (Pneumoconiosis) Compensation Scheme (1943). After this date large numbers of coal-miners, particularly in South Wales, were "certified" and "suspended" from further work in the industry. There was at that time considerable evidence that coalworkers' pneumoconiosis was a different disease from "classical" silicosis, as described in South Africa, but, in the absence of any direct evidence about the progression rates inside and outside mining, it no doubt appeared safer to suspend miners with pneumoconiosis from the environment which appeared to have caused it.

Böhme (1933) appears to have been the first to point out that radiological progression did take place after exposure to dust had ceased amongst coal-miners with "silicosis". At first, it was uncertain whether the condition he was referring to was the same as that seen in South Wales, but the same phenomenon was soon observed in a short series by Aslett, Davies, and Jenkins (1943) and was later confirmed by Stewart, Davies, Dowsett, Morrell, and Pierce (1948). Later, after Davies and Mann (1949) had differentiated simple pneumoconiosis from progressive massive fibrosis (P.M.F.), Davies, Fletcher, Mann, and Stewart (1949), on a small series, showed that there was no significant difference between the frequency with which progression of P.M.F. was seen in the radiographs amongst those who left mining and those who continued to work as miners. (As "frequency of progression" is a somewhat clumsy phrase, "rate of progression" has been used throughout this paper.) It was against this somewhat uncertain background that the new regulations governing pneumoconiosis under the National Insurance (Industrial Injuries) Act, 1946, were introduced. These abolished the power of suspension (except in cases of infectious tuberculosis), and at present large numbers of miners with P.M.F., particularly in South Wales, are continuing at work in the mines. It is therefore of importance that further information should be obtained on this subject.

It is, however, not a simple matter to get definite information. The most satisfactory method would be to allocate at random miners with P.M.F. into

two groups and arrange that one group continued mining and the other left mining, and to radiograph again both groups after two or three years. But this would be exceedingly difficult—if not impossible. One is therefore forced to be content with observing the cases as they " select " themselves into the two groups, and the possible biases associated with such self-selection are only too clear. The more disabled cases, for instance, will probably leave mining and seek lighter employment outside. Similarly, those who leave mining will, on the average, have a lower income, even when pensions are taken into account, and this might influence the progression rate independently of the dust exposure.

Deaths introduce further complications. Some of the deaths can be considered as the extreme form of progression; others, of course, are due to other causes. This would be unimportant if the two groups had been randomly allocated, but becomes important when one is relying on observation of self-selected groups. There is also the further difficulty that those dying of P.M.F. (and from all other causes except accidents and possibly some types of vascular disease) will tend to leave mining some time before death. Deaths thus tend to occur predominantly in the groups with " non-mining "or " mixed " occupations and not in the " mining " group.

The only solution to this problem appears to be the restriction of the observation to such an early type of P.M.F. that it is highly unlikely that it will be a cause of death during the planned period of observation. Fortunately we have evidence that death rates amongst those with " A " shadows (the earliest stage of P.M.F.), standardized for age, in the 2·6 years following a survey are no higher than those for miners and ex-miners whose radiographs show no pneumoconiosis, while there is some evidence that those with " B ", " C ", and " D " shadows (the more advanced stages of P.M.F.) have a somewhat reduced life expectancy (Carpenter and Cochrane, 1956). The best approach would therefore appear to be to use as large and as complete a population of men with " A " shadows as possible and follow them for a relatively short period, realizing at the same time that any difference amongst those outside mining compared with those in mining may be due to self-selection.

The only previously published group approaching this description is that used by Miall, Oldham, and Cochrane (1954), when investigating the effect of isoniazid on the progression rate of P.M.F. They also analysed the effect of " dusty " and " non-dusty " occupations. The difference was not significant but the size of the groups made the test somewhat insensitive. The trend suggested that there was a higher progression rate in the dusty group.

Material

Details of the first and second Rhondda Fach surveys have already been published (Cochrane, Cox, and Jarman, 1952, 1955). Ninety-five per cent. of the miners and ex-miners were radiographed on both occasions. This paper is concerned with those whose radiographs showed P.M.F. at the time of the first survey, and, in particular, with the differences between radiographs taken during the two surveys in 1950/51 and 1953. The material has been subdivided into those with " A " shadows at the time of the first survey and those with " B ", " C ", and " D " shadows.

The pairs of radiographs were read, without any knowledge of the men's ages or industrial histories, by two pairs of readers, A. L. C. and Dr. Idris Davies, and Drs. S. Rae and P. J. Chapman. Each pair of readers classified the films separately. If there was any disagreement, an agreed reading was obtained with all four readers present. The films were classified—as far as P.M.F. is concerned—into " no change " and " definite progression ". The industrial histories were obtained direct from the miners and ex-miners at the time of the two surveys. From the details obtained, they have been classified into " mining " (including surface work), " outside mining ", and " mining and outside " for the period between the two surveys.

Results

Table 1 shows details of the follow-up of the 364

TABLE 1

FOLLOW-UP OF MINERS AND EX-MINERS WITH PROGRESSIVE MASSIVE FIBROSIS (CATEGORY " A ") 1950/51 (SPUTUM POSITIVE AND NEGATIVE) RADIOGRAPHED AGAIN IN 1953

Age Group	No.	No. Dead	No. Remaining	No. Radiographed 1953	% Radiographed	Sputum Positive 1950/51	No. Remaining
15–24	4	–	4	4	100·0	–	4
25–34	45	–	45	45	100·0	–	45
35–44	87	2	85	85	100·0	1	84
45–54	90	2	88	88	100·0	1	87
55–64	73	2	71	70	98·6	–	70
65 +	65	7	58	50	86·2	–	50
Total ..	364	13	351	342	97·4	2	340

TABLE 2

RADIOLOGICAL PROGRESSION OF CATEGORY "A" SHADOWS IN SPUTUM-NEGATIVE CASES BETWEEN AGES OF 25 AND 64 ANALYSED BY OCCUPATION

Occupation between Surveys	Age	No. Radiographed 1950/51	No. Dead	No. not Radiographed 1953	No. Sputum Positive 1950/51	No. Remaining	Definite Progression	%	Overall %
In mining	25–34	17				17	8	47·1	27·4
	35–44	35				35	10	28·6	
	45–54	34	1 (1)			33	8	24·2	
	55–64	28				28	5	17·9	
Outside mining ..	25–34	21				21	7	33·3	17·0
	35–44	40	1 (2)		1	38	10	26·3	
	45–54	49			1	48	3	6·3	
	55–64	43	2 (3) (4)	1		40	5	12·5	
Mining and outside	25–34	7				7	1	14·3	25·0
	35–44	10	1 (5)			9	1	11·1	
	45–54	7	1 (6)			6	2	33·3	
	55–64	2				2	2	100·0	
Other dusty occupations	35–44	2				2	–	–	
Total ..	All ages	295	6	1	2	286	62	21·7	

Causes of deaths : (1) Cardiac failure, coronary atheroma, and pulmonary infarction
(2) Coronary thrombosis, arterio-sclerosis, and hypertension. Diabetes
(3) Cerebral embolism, heart failure, hypertension
(4) Pneumonia, cancer of the liver
(5) Carcinoma of stomach, generalized secondary metastases
(6) Cachexia, carcinoma of stomach

miners and ex-miners whose radiographs were thought to have " A " shadows at the time of the first survey. At the time of the second survey, 2·6 years later, 13 of these were dead and nine refused to be radiographed, but only one of the latter was under 65. Two were found to have tubercle bacilli in their sputum at the time of the first survey.

For the analysis into those who continued mining and those who did not, we have discarded those under 25 because there are so few; we have also discarded those over 65 as they will be leaving mining in any case. We have also excluded the two cases with sputa positive for tubercle bacilli as there is no doubt about advising them to leave mining.

Table 2 gives the comparison between the progression rates by age in the three occupational groups. It should be noted that the deaths that occurred were not apparently related to chest disease. In Tables 3 and 4 and the figure the two main groups have been further subdivided and for the purpose of analysis " surface " and " other underground workers " (Table 3) have been grouped together, and those classified as " mixed " (Table 4) have been excluded as they were a heterogeneous small group.

In this way we have four groups of workers with men under and over the age of 45 in each. These 20-year age groups are very wide and slight variations of mean age occur between one group and the next within the same age group. Thus the mean age of men doing outdoor work in the age group 45 to 64 is 51 years while the mean age of the corresponding group doing indoor work is 56 years. This, however, is the largest difference of this type. But age is a significant factor which affects the percentage of men who progress. The analysis described below was therefore done using the actual age of the subjects, as in this way allowances for these minor variations may be made.

TABLE 3

FURTHER ANALYSIS OF MINERS BY TYPE OF OCCUPATION

Occupation between Surveys	Age	No. Radiographed 1950/51	No. Dead	No. not Radiographed 1953	Sputum Positive 1950/51	No. Remaining	Definite Progression	%	
Colliers and other face-workers including firemen	25–44	24				24	10	41·7	40·0
	45–64	6				6	2	33·3	
Other underground workers	25–44	19				19	5	26·3	22·0
	45–64	41	1 (1)			40	8	20·0	
Surface workers	25–44	9				9	3	33·3	25·0
	45–64	15				15	3	20·0	
Total	All ages	114	1	–	–	113	31	27·4	

For cause of death, see footnote to Table 2

TABLE 4

FURTHER ANALYSIS OF THOSE WORKING OUTSIDE MINING BY TYPE OF OCCUPATION

Occupation between Surveys	Age	No. Radiographed 1950/51	No. Dead	No. not Radiographed 1953	Sputum Positive 1950/51	No. Remaining	Definite Progression	%	
Outdoor	25–44	18				18	6	33·3	27·0
	45–64	19				19	4	21·1	
Indoor and unemployed	25–44	36	1 (2)		1	34	8	23·5	13·3
	45–64	59	1 (4)	1	1	56	4	7·1	
Mixed	25–44	7				7	3	42·9	15·0
	45–64	14	1 (3)			13	–	–	
Total	All ages	153	3	1	2	147	25	17·0	

For causes of death, see footnote to Table 2

The first point is that the percentage progressing declines with age in each of the four groups of workers. This decline may be taken as 7·3% ±2·6% with every additional 10 years of life, within the age limits 25 to 64. It should be noticed, however, that the number of our cases in the younger end of this age range is inevitably small.

This decline with age is significant. Hence the percentage progressing in the four groups of workers and the comparisons of the groups are given as though each group were the same age. This age is taken as the mean age of all the men, which is 46·7 years. This may be done since the decline in the percentage progressing with age is similar in each of the four occupational groups.

Table 5 summarizes the mean percentage progressing in the four occupational groups, adjusted for age, together with the standard errors of these means. Table 6 compares the percentage progressing in the different groups. The difference of 9% between all the miners compared with all those working outside the mines is suggestive but not quite significant. The differences between faceworkers and other mineworkers and outdoor workers and indoor workers are not significant. It will, however, be noticed that contrary to previous findings our outdoor workers showed more progression than did indoor workers, which we attribute to the heavy work the latter were doing.

TABLE 5

PERCENTAGE OF MEN PROGRESSING IN DIFFERENT OCCUPATIONAL GROUPS WHEN AGE IS STANDARDIZED AT 46·7 YEARS

Occupational Group	Mean % Progressing Standardized for Age	Standard Error of Mean (%)
All mineworkers ..	26·8	± 3·84
Face workers	35·6	± 7·74
Other underground and surface workers ..	23·8	± 4·49
All outside mining ..	17·8	± 3·62
Outdoor work ..	25·8	± 6·72
Indoor work and unemployed	14·4	± 4·32

TABLE 6

COMPARISONS OF MEAN PERCENTAGE PROGRESSING IN DIFFERENT OCCUPATIONAL GROUPS STANDARDIZED FOR AGE

Comparisons	Difference of Mean Percentages	Standard Error of Difference (%)	Significance of Difference
Mineworkers—non-miners ..	9·0	± 5·28	0·1 > P > 0·05
Faceworkers—other mineworkers	11·8	± 9·06	0·3 > P > 0·2
Outdoor—indoor	11·4	± 8·03	0·2 > P > 0·1
Faceworkers—indoor workers ..	21·2	± 9·01	P = 0·02

The difference between faceworkers and indoor workers is 21%. This difference, which on a "t" test has a probability of occurring by pure chance of 0·02, is almost certainly real, even though it is the most extreme comparison that could have been made.

The analysis of the "B", "C", and "D" shadows gives a different picture. Table 7 shows the

TABLE 7

FOLLOW-UP OF MINERS AND EX-MINERS WITH PROGRESSIVE MASSIVE FIBROSIS (CATEGORIES "B", "C", AND "D") 1950/51 (SPUTUM POSITIVE AND NEGATIVE)

Age	No.	No. Dead	No. Remaining	No. Radiographed 1953	%	Sputum Positive 1950/51	No. Remaining
15–24	1	–	1	1	100·0	–	1
25–34	25	–	25	22	88·0	2	20
35–44	121	3	118	115	97·5	2	113
45–54	137	5	132	120	90·9	3	117
55–64	176	14	162	150	92·6	2	148
65+	161	37	124	109	87·9	–	109
Total ..	621	59	562	517	92·0	9	508

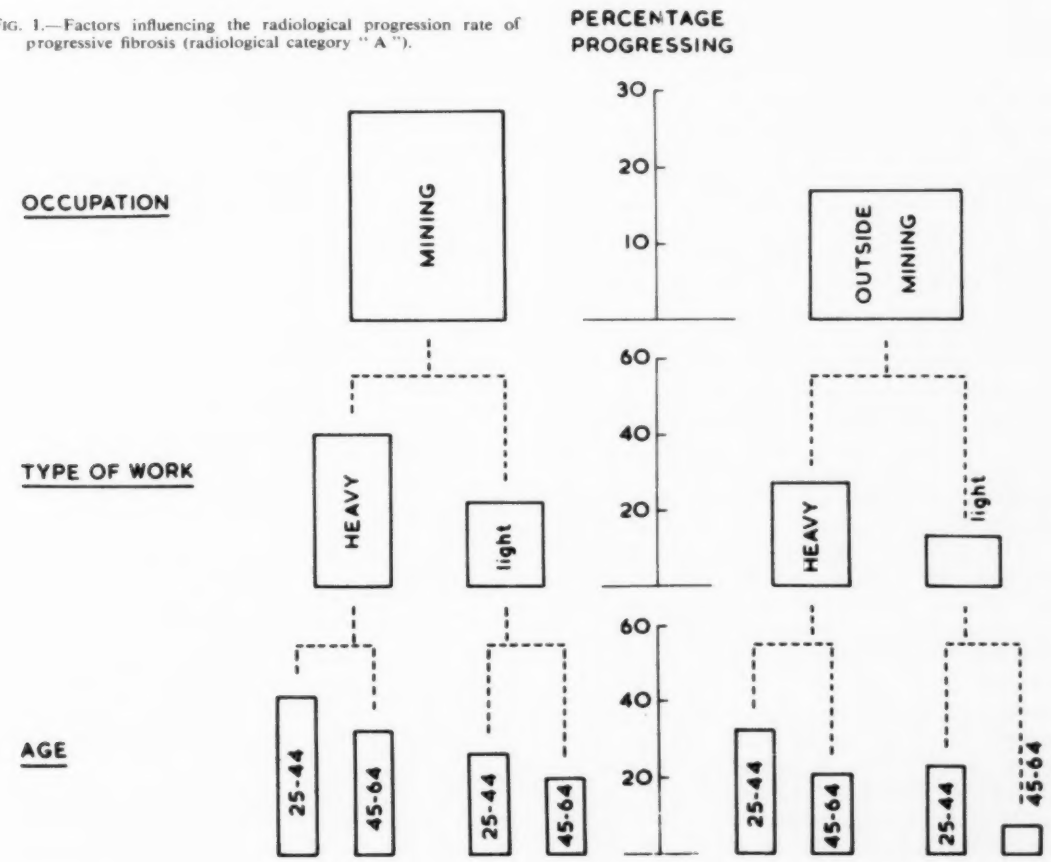
TABLE 8

RADIOLOGICAL PROGRESSION OF CATEGORIES "B", "C", AND "D" SHADOWS IN SPUTUM-NEGATIVE CASES BETWEEN THE AGES OF 25 AND 64 ANALYSED BY OCCUPATION

Occupation between Surveys	Age	No. Radiographed 1950/51	No. Dead	No. not Radiographed 1953	No. Sputum Positive 1950/51	No. Remaining	Definite Progression	%	Overall %
In mining	25–34	3	–	–	–	3	1	33·3	35·1
	35–44	19	–	–	–	19	10	52·6	
	45–54	27	1	1	–	25	9	36·0	
	55–64	27	–	–	–	27	6	22·2	
Outside mining	25–34	22	–	3	2	17	6	35·3	32·2
	35–44	97	3	3	2	89	35	39·3	
	45–54	101	4	11	3	83	32	38·6	
	55–64	146	14	12	2	118	26	22·0	
Mining and outside	25–34	–	–	–	–	–	–	–	41·2
	35–44	5	–	–	–	5	3	60·0	
	45–54	9	–	–	–	9	4	44·4	
	55–64	3	–	–	–	3	–	–	
Total	25–64	459	22	30	9	398	132	–	33·2

extent of the follow-up and Table 8 the division into those who left mining and those who continued in mining. It will be observed that although the progression rates in the two groups are similar there is every possibility of a bias having been introduced either by the large number of lapses or by the deaths in the non-mining group, and that it would therefore be unwise to deduce anything from this.

FIG. 1.—Factors influencing the radiological progression rate of progressive fibrosis (radiological category "A").



Discussion

This study has confirmed the fact noted by many observers that P.M.F. progresses after leaving mining. We have not been so successful in our attempt to confirm the work of Davies *et al.* (1949) which suggested that the rate of progression was the same whether the miner left mining or not. Our results have shown that, in addition to progression being influenced by age (the younger men having the higher rate), it is very probably influenced by working in the mines and by doing heavy work whether in mining or not. The importance of the last two factors cannot be considered as finally established but they are the factors that would be the easiest to control. Future research may show significant differences where ours are only suggestive, and it may seem reasonable to suggest that dust exposure is the effective agent in mining life. It should, however, be remembered that dust exposure is highly correlated with hard work in mining and that it is probable that hard work and light work in mining are harder than their corresponding processes outside mining. For the moment it would appear that the hypothesis that " hard " work is the effective factor must be accepted as the simplest explanation, although the effect of dust exposure cannot be excluded. As our groups were self-selected (as also were those of Davies) the probable direction of the bias introduced by the self-selection becomes of great importance. Most medical observers agree that the less fit, in general, tend to leave mining, and they might well be expected to be the more rapid progressors. If this is so—it must be stressed that this is a matter of opinion and not of fact—then our findings would be more significant as the excess of progressions would have been achieved against the bias.

The point at issue is an important one and clearly needs further investigation. There are two possible lines of approach: (i) A longer follow-up of the present series; this would certainly increase the number of progressors but would run into trouble from the point of view of lapses, and would not solve the problem of self-selection. (ii) A properly controlled trial with random allocation of miners into " mining " and " non-mining " groups; this presents enormous practical difficulties, but it could be attempted if the problem is considered sufficiently important.

As regards the immediate practical effects of our findings, two points can be made. As the rate of progression of P.M.F. decreases with age, we have an additional argument for postponing the attainment of category 2, simple pneumoconiosis, as long as possible amongst coal-miners (if we cannot prevent it altogether), for at that stage the miner becomes increasingly at risk to the development of P.M.F. As regards the advice to be given to miners with " A " shadows, the situation is not very much clearer. The facts should be explained to them and all psychological and economic factors taken into account. But it now seems reasonable to bring some pressure to bear on young men with " A " shadows to leave the coal face and, if possible, re-train for some light indoor job.

Summary

The new regulations governing pneumoconiosis under the National Insurance (Industrial Injuries) Act (1946) abolished the power of suspension of miners (except those with infectious tuberculosis), and large numbers of miners with progressive massive fibrosis (P.M.F.) continue to work in the mines.

It is therefore of importance to determine the effects of occupation on the radiological progression rate of cases of massive fibrosis. The theoretical and practical difficulties of such an investigation are discussed.

Of 364 miners and ex-miners whose radiographs showed the earliest stage of P.M.F. at the time of the first Rhondda Fach Survey (1950/51), 342 were radiographed again in 1953.

An analysis by age and occupation of these cases suggests that three factors—age, mining, and hard work—are likely to affect the progression rate.

(*a*) With age there is a significant decline in the percentage progressing in all these men. This has a value of 7·3% ± 2·6% for every additional 10 years of life within the age limits 25-64 years.

(*b*) All mineworkers showed a 9% excess of progression over those who had left mining; this difference is suggestive but not statistically significant. The differences between coal-face workers and other mineworkers, and outdoor workers and indoor workers were not significant.

(*c*) The coal-face workers showed a significant excess of 21% progression over men employed in light indoor work.

It is therefore reasonable to advise young miners with early P.M.F. to leave the coal face and re-train in some more sedentary occupation.

This work was carried out under the general direction of the Rhondda Fach Scheme Advisory Committee and we should like to express our thanks to them for their help, encouragement, and advice. They are not in any way responsible, however, for the views expressed by the authors in this paper.

We should particularly like to thank the other members of the epidemiological team at the Pneumoconiosis Research Unit, who played a major part in both surveys;

Dr. T. F. Jarman and his M.M.R. team who worked with us during the two surveys; the two field research teams of the National Coal Board under Dr. P. J. Chapman and Dr. S. Rae who worked with us during the second survey; Dr. C. M. Fletcher, previously Director of the Unit; Dr. J. C. Gilson, the Director; Dr. Idris Davies, Dr. W. E. Miall, and Mr. P. D. Oldham, members of the scientific staff of the Pneumoconiosis Research Unit; the numerous officials of the National Coal Board and the National Union of Mineworkers who assisted us in the surveys; the Cardiff Pneumoconiosis Medical Panel of the Ministry of Pensions and National Insurance and many others who lent us films; the Medical Officer of Health, Rhondda Urban District, and his department; and above all, the miners and exminers of the Rhondda Fach without whose help this work would have been impossible.

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Brit. J. industr. Med., 1956, **13**, 184.

PNEUMOCONIOSIS IN CENTRAL INDIAN COAL-MINES

BY

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Extensive surveys carried out in Europe and America have shown the incidence of coalworkers' pneumoconiosis to be widespread (Flinn, Seifert, Brinton, Jones, and Franks, 1941; Fletcher, 1955). In India, however, the prevalence of this disease has never been investigated, and a report published by the government of India in 1946 (Deshpande, 1946) stated that there was no conclusive evidence that pneumoconiosis occurred to any great extent. The present paper describes five cases of pneumoconiosis in Indian coal-miners.

Mining Conditions

The group of mines where these five patients have worked are in the state of Madhya Pradesh in central India.

In each mine the environment is similar. The coal seams of ligno-bituminous or semi-bituminous coal are usually 4-6 ft. thick and 7-8% of the mined material consists of shale. The ash content of the coal varies between 18 and 28%, 10% of which is probably free silica. Only a rough estimate of the free silica is possible since there are no available measurements of the free silica content of the dust in Indian coal-mines.

The roof and floor of the mines consist mainly of shale and the mines are dry except during the rainy season.

All the mines are either unmechanized or only partly mechanized. Three shifts of eight hours each are worked. "Hand holing" (undercutting the coal face and digging holes into it for insertion of explosive) is done by the miner with an ordinary pick. After firing, the miner again uses the pick to bring down the loosened coal. Large lumps are broken into smaller ones for loading into coal cars. All these processes are dusty and no dust suppression is used in any of the mines. Power-driven coal-cutters and drills, introduced during the past six years, aggravate the dust problem.

Ventilation depends on the "natural" method, with "upcast" and "downcast" shafts placed at intervals and aided by exhaust fans at the mouths of some of the shafts. The absence of coal gas enables the miners to use naked kerosene oil lamps for illumination. These give poor illumination and produce much soot. The prevailing system of piece rate wages leads miners to ignore the largely invisible dust clouds after blasting in order to bring down as much coal as quickly as possible.

Case Reports

Case 1.—Sahadeo, aged 40 years, had been a miner for 20 years. He had no symptoms, disability, or abnormal physical signs. The erythrocyte sedimentation rate was 20 mm. hour (Westergren). A chest radiograph showed uniformly distributed, homogeneous nodulation in both lung fields with a tendency to coalescence in the middle zones.

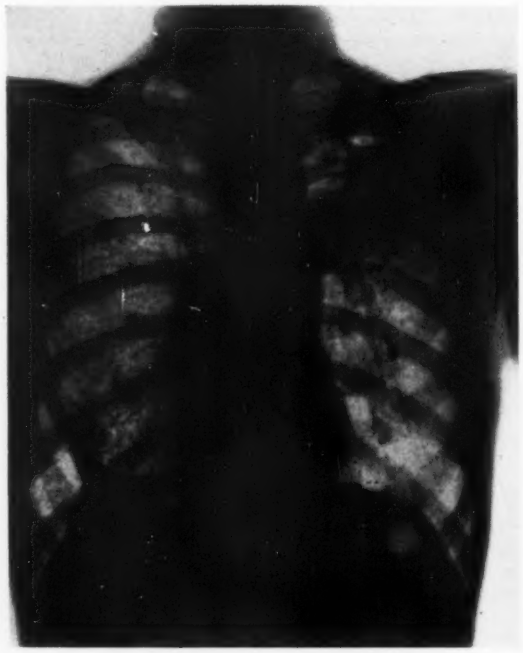

FIG. 1.—Case 2.

Case 2.—Swarupnarayan, aged 52 years, had been a miner for 31 years. Five years previously disability had compelled him to give up mining. Since then he had been employed as a watchman at the pit mouth. He complained of exertional breathlessness and recurrent attacks of dyspnoea for the past seven years, and minimal cough productive of a small amount of mucoid sputum.

He had had an attack of lobar pneumonia 10 years before, from which he had made a complete recovery. The father had been a coal-miner and had died of a long-standing respiratory complaint.

On physical examination, slight clubbing of the fingers was seen.

There was moderate kyphosis. The percussion note was impaired, breath sounds and vocal resonance were diminished, and medium-pitched rhonchi were heard in both lower zones.

A chest radiograph (Fig. 1) showed progressive massive fibrosis in the left upper zone on a background of advanced simple pneumoconiosis (international classification, 3B 0/3).

The diaphragm, particularly the right dome, was distorted, due to adhesions.

The E.S.R. was 17 mm. in one hour (Westergren) and Hb 68%.

No acid-fast bacilli were seen on repeated examinations.

Disability was assessed at 40%.

Case 3.—Bharosa, aged 40 years, had been a miner for 22 years. He had been compelled by disability to give up mining three years before and since this time had been employed as a casual labourer on the surface.

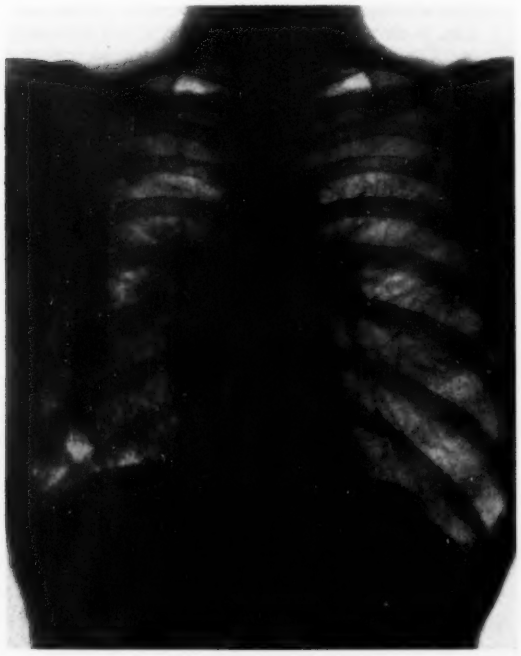

FIG. 2.—Case 3.

He was breathless on exertion. The percussion note was impaired, and breath sounds and vocal resonance were diminished with a few basal rales in both lungs.

A chest radiograph (Fig. 2) showed progressive massive fibrosis in the right side on a background of moderately advanced simple pneumoconiosis (international classification 2C 5/0). There were diaphragmatic adhesions on the right side.

The E.S.R. was 15 mm. in one hour (Westergren) and Hb 75%.

No acid-fast bacilli were found in the sputum.

Disability was assessed at 30%.

Case 4.—Jogeswar, aged 40 years, had been a miner for 20 years. He gave up six years before because of disability and at present was employed in odd jobs on the surface.

He had been breathless on exertion for eight years.

A chest radiograph (Fig. 3) showed well marked simple pneumoconiosis with an early massive shadow on the right (international classification 3A 2/0).

No acid-fast bacilli seen in the sputum.

The E.S.R. was 22 mm. in one hour (Westergren) and Hb 65%.

Disability was assessed at 35%.

Case 5.—Ramlal, aged 45 years, had been a miner for 15 years, for the past 14 years as a supervisor underground.

He had had increasing breathlessness on exertion for

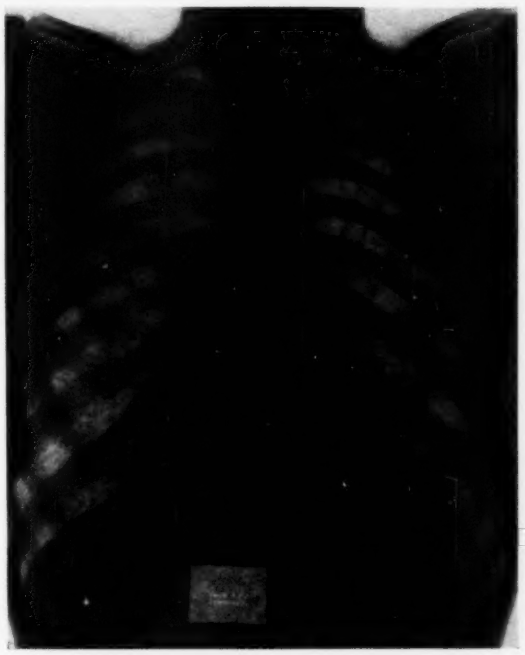

FIG. 3.—Case 4.

FIG. 4.—Case 5.

the past five years, and recurrent attacks of cough with sputum, particularly in the winter. For the past two years he had only been able to work one to two hours each day underground on account of breathlessness.

The percussion note was impaired, and breath sounds were diminished with rales in both lungs.

A chest radiograph (Fig. 4) showed a moderate degree of simple pneumoconiosis with an early massive shadow on the right side (international classification, 2A 2/0), and adhesions at the right base.

The E.S.R. was 17 mm. in one hour, and Hb 70%. No acid-fast bacilli seen on repeated examinations of the sputum.

Disability was assessed at 35%.

Discussion

The four cases showing radiological evidence of complicated pneumoconiosis have been observed by the author for the last six years. They have suffered only from shortness of breath; cough as a major complaint, chest pain (despite radiographic evidence of pleural adhesions) and melanoptysis have been absent. There have been no clinical signs of tuberculosis and repeated examinations of the sputum for acid-fast bacilli have been negative. The E.S.R. in all these cases showed a slight increase, the average figure for healthy Indian males being 3 to 15 mm. in one hour (Napier and Das Gupta, 1945).

Summary

Five cases of coalworkers' pneumoconiosis in Indian coal-miners working in bituminous mines are described.

The dustiness of the mines, due to the methods of mining and absence of dust suppression, are considered responsible for the development of the disease.

The author is grateful to Dr. S. W. Fisher, Pneumoconiosis Medical Panel of the Ministry of Pensions and National Insurance, London, for expressing his valuable opinion regarding three of the radiographs of Cases 2, 3, and 5, and for suggesting useful lines of investigation.

I also wish to thank my employers, the Associated Cement Co. (India), for allowing me to publish these cases.

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Brit. J. industr. Med., 1956, **13**, 187.

A STUDY OF DUST TOXICITY USING A QUANTITATIVE TISSUE CULTURE TECHNIQUE

BY

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A number of workers have employed tissue culture techniques in pneumoconiosis research since Fenn (1921) examined the phagocytosis of quartz and coal by rat exudate leucocytes. However, most attention has been directed to the degree of phagocytosis achieved rather than to evaluating accurately the toxicity of dust to the phagocytic cell. Moreover, the techniques used did not provide concordant results in the hands of different workers. For example, Policard, Doubrow, and Boucharlat (1929) found that chick embryo macrophages were damaged by ingested quartz whereas Lauche (1931) observed no effect. Kasten (1939) and Belt, Friedmann, and King (1947) found coal was phagocytosed more readily than quartz whereas Buckup (1950) did not detect any difference. A quantitative study of the phagocytosis of quartz was undertaken by Marwyck and Fischer (1951).

Policard and Collet (1953) have injected dusts intraperitoneally into rats and examined the exudate phagocytes after five to 20 hours in an attempt to estimate dust toxicity. However, the phagocytes were not maintained in tissue culture and their observations were qualitative only.

A technique has been recently described (Marks and Mason, 1956) which permits a quantitative assessment of dust toxicity in tissue culture in three days. It has now been used to compare the toxicity of a number of dusts of interests in the field of pneumoconiosis and to examine the effect of protective agents. The chief purpose of the investigation was to determine whether the short-term toxicity of dusts as seen in tissue culture is related to their reported effect *in vivo* in animal experiments. In these, the amount and maturity of silicotic type lesions have usually been taken as an index of pathogenicity in experiments lasting several months or sometimes one or more years.

Methods and Materials

The technique employed in the present investigation was the same as that previously recorded using guinea-pig exudate cells but the explanation of the symbols used to record dust toxicity will be repeated for convenience:—

- $+$ Considerably fewer cells adhere to the glass than in the controls. They are optically denser and less active than normal cells, a large proportion being partially or completely rounded off.
- $++$ Less than 10% of the cells remain on the glass. Most of the survivors are optically dense whether rounded off or not.
- $+++$ Fewer than 50 cells remain (inoculum $= 2 \times 10^6$ cells).

Intermediate degrees of damage designated trace, $+\pm$, and $++\pm$, were also recognized.

Experience showed that determinations of dust toxicity were most reproducible when a moderate degree of damage was taken as the end-point of titrations. The end-point, which can conveniently be used to express the degree of toxicity, was therefore defined as the smallest concentration of dust (in μg. per 10^6 cells) required to produce in three days cell damage of the degree $+\pm$ or $++$ (standard damage). A reference dust (tridymite 2612) was normally titrated in each experiment as a check on the experimental conditions.

With the exception of four dusts presented by Dr. B. M. Wright, the materials used in the present work were prepared at the Safety in Mines Research Establishment, Sheffield. Information available about their size is summarized in Table I.

Most of the dusts were fractions graded by size primarily prepared for the animal experiments of Professor E. J. King and his colleagues. The particle size distribution was determined by counting and sizing with the optical or electron microscope. The specific surface was calculated from the size distribution and for several of the dusts checked by air permeability determinations. These gave good agreement for specific surfaces between 0·5 and 3 m.^{2}/g. for isometric materials such as felspar, silica modifications, and coal. The plate-shaped minerals kaolin and mica were used in

TABLE 1
SPECIFIC SURFACE AND SIZE DISTRIBUTION OF DUST SAMPLES EMPLOYED IN THE PRESENT WORK

Identification		Specific Surface ($m.^2/g.$)	Mass % in Given Size Ranges (μ)						
			< 0·23	0·23 to 0·45	0·45 to 0·9	0·9 to 1·8	1·8 to 3·6	3·6 to 7·2	> 7·2
Tridymite	2612	2·2	0·2	0·9	10·6	47·8	40·5	0	0
,,	2424	0·6	0	0	0	0·1	7·2	82·0	10·7
Cristobalite	2571	2·3	0·2	1·4	15·8	42	40·5	0	0
Quartz	2531	8·3	13·1	47·0	39·8	0	0	0	0
,,	2866	2·3	0	0·1	6·6	84·9	8·4	0	0
Vitreous silica	2835	1·75	0·2	0·6	5·7	42·8	44·5	6·5	0
Bituminous coal	1849	3·4	0·1	1·7	13·6	42·9	27·5	14·3	0
,, ,,	3832	1·1	0	0	0	2·4	16·6	81·0	0
,, ,,	3968	2·5	0	0	0·2	36·8	63·0	0	0
Steam coal (Wright)	4311	0·9	0	0	1·4	5·7	6·5	26·2	60·1
Anthracite	3731	1·2	0	0	0	2·3	32·9	48·1	16·7
,,	3965	2·2	0	0	0·5	25·3	66·6	7·6	0
,, (Wright)	4312	1·3	0	0	1·7	7·2	21·1	44·4	25·6
Felspar	109	3·7	0	8·3	41·2	43·8	6·7	0	0
$AlPO_4$	2518	2·9	1·4	4·7	18·7	47·7	27·4	0	0
$AlPO_4$	2507	3·1	1·7	5·7	21·0	55·8	15·9	0	0
CaF_2	2996	2·4	0·2	2·2	31·3	51·8	14·5	0	0
$FePO_4$	2267	2·3	0·2	3·2	21·1	43·6	31·9	0	0
Kaolin	1876	10 approx.	Not available						
Mica	2431	10 ,,	,, ,,						
Alumina	1342	100 ,,	,, ,,						
,,	1336	3 ,,	,, ,,						

fractions below 4 μ Stokes diameter, and the projected diameters of the particles did not exceed 10 μ. However, as the ratio of diameter to thickness was unknown and variable, the specific surface could not be determined accurately and the value of 10 $m.^2/g.$ cited is only a rough estimate.

Results

Different Forms of Silica.—The effect on replicate leucocyte cultures of vitreous silica and the three crystalline forms, tridymite, cristobalite, and quartz, was examined. The samples chosen were fairly similar in particle size, their specific surfaces approximating to 2 $m.^2/g.$ The toxicity titrations obtained in a representative experiment are shown in Table 2. Tridymite and cristobalite behaved similarly, producing the standard degree of cell damage in a concentration of 7·5 μg. per 10^6 cells. Quartz and vitreous silica were eight times less toxic, the standard toxic dose being 60 μg. per 10^6 cells in both cases.

Particle Size.—The effect of dust samples with different ranges of particle size was studied using tridymite and quartz. The results of typical titrations presented in Table 3 show that toxicity increased with the specific surface of the dust sample. King, Mohanty, Harrison, and Nagelschmidt (1953a) observed a similar relation *in vivo* between the fibrogenic activity and specific surfaces of flint dust samples administered in equal weights.

Silicates.—One sample each of felspar, mica, and kaolin dusts was examined. The specific surfaces of

TABLE 2
EFFECT OF DIFFERENT FORMS OF SILICA ON EXUDATE CELL CULTURES

Dust Sample		Specific Surface ($m.^2/g.$)	Toxicity of Given Dust Concentrations ($\mu g./10^4$ cells)							
			120	60	30	15	7·5	3·7	1·8	0·9
Tridymite	2612	2·2	+ + +	+ + +	+ + +	+ +	**+ ±***	+	Trace	0
Cristobalite	2571	2·3	+ + +	+ + +	+ + +	+ +	**+ ±**	+	Trace	0
Quartz	2866	2·3	+ + ±	**+ ±**	Trace	Trace	0	0	0	0
Vitreous silica	2835	1·65	+ + +	**+ +**	+	Trace	0	0	0	0

*Figures in bold type are the titration end-points.

TABLE 3
EFFECT OF SPECIFIC SURFACE ON TOXICITY IN EXUDATE CELL CULTURES

Dust Sample		Specific Surface ($m.^2/g.$)	Toxicity of Given Dust Concentrations ($\mu g./10^4$ cells)						
			120	60	30	15	7·5	3·7	1·8
Tridymite	2612	2·2	+ + +	+ + +	+ + +	+ +	**+ ±***	+	Trace
Tridymite	2424	0·6	+ + +	+ +	**+ ±**	Trace	0	0	0
Quartz	2531	8·3	+ + +	+ + ±	**+ ±**	Trace	.	.	.
Quartz	2866	2·3	+ +	**+ ±**	Trace	0	.	.	.

*Figures in bold type are the titration end-points.

TABLE 4
COMPARISON OF EFFECTS OF SILICATES AND QUARTZ AND TRIDYMITE ON EXUDATE CELL CULTURES

Dust Sample		Specific Surface ($m.^2/g.$)	Toxicity of Given Dust Concentrations ($\mu g./10^6$ cells)					
			120	60	30	15	7·5	3·7
Kaolin	1876	10	+++	+++	**++***	Trace	.	.
Felspar	109	3·7	+++	**++**	Trace	0	.	.
Mica	2431	10	**++**	+	0	0	.	.
Quartz	2531	8·3	+++	++	**+±**	Trace	.	.
Tridymite	2612	2·2	+++	+++	+++	+++	**++**	+

* Figures in bold type are the titration end-points.

the latter two samples at an estimated 10 $m.^2/g.$ were probably considerably greater than those of the other dusts investigated. The silicates proved unexpectedly toxic, the effect of kaolin and felspar being as great as that of quartz although much less than that of tridymite. Mica was less toxic than the other two silicates. Details of an experiment in which silicates, quartz, and tridymite were compared are given in Table 4.

Coal.—Phagocytes appeared to suffer no harm from coal unless burdened with very large amounts. With such dosages it was uncertain whether the rounding off of the cells and their detachment from the glass should be considered as evidence of toxicity or merely of overloading. Many cells retained their activity despite the ingestion of very large amounts of coal but it should be noted that except in sample 1849 there were no very small particles. When coal was administered as a suspension in Ringer's solution the standard degree of cell damage was produced by all three samples of anthracite in a dosage of 240 $\mu g.$ per 10^6 cells but not by bituminous or steam coal. It was noted that the latter varieties, especially sample 3968, suspended poorly and appeared to be taken up by the phagocytes less well than anthracite. An attempt was made to improve the dispersion of coal particles by first suspending them in concentrations of 6 mg. per ml. in 66% serum or in a preparation of 1% (approximately) lecithin in Ringer's solution. Better coal suspensions were obtained in both cases and the phagocytosis of the bituminous varieties greatly increased. With these modifications the effects of the bituminous and steam coal samples approached those of the anthracite without quite equalling them. It appears likely, therefore, that differences observed between the effects of bituminous or steam coal and anthracite on leucocyte cultures were due only to the difficulty in dispersing the former in suspensions.

The toxicity of combinations of kaolin or felspar with different coals appeared to be additive.

Other Types of Dust.—The following dusts were examined which had previously been studied in animal experiments (Professor E. J. King, personal communication): ferric phosphate, calcium fluoride, and two types each of aluminium phosphate and alumina. They are described in Tables 1 and 5.

The highest concentration of these dusts tested was 120 $\mu g.$ per 10^6 cells which was normally in excess of what could be phagocytosed. Ferric phosphate and α-alumina had a negligible effect on leucocyte cultures. The toxicity of aluminium phosphate was definite but not sufficient to produce standard cell damage and was unrelated to the crystalline form. Alumina which had been heated to 820° C. produced standard cell damage in a concentration of 120 $\mu g.$ per 10^6 cells. Calcium fluoride produced the degree of damage designated ++ in a concentration of 60 $\mu g.$ per 10^6 cells, being the only dust of the group to approach quartz in its toxicity. The results obtained in a typical experiment are shown in Table 5. They demonstrate a correlation between toxicity for leucocytes *in vitro* and the

TABLE 5
EFFECT ON EXUDATE CELL CULTURES OF DUSTS WITH DIFFERENT FIBROGENIC ACTIVITIES

Dust Sample		Mineral Type	Fibrogenic Activity *in vivo*	Toxicity of Given Dust Concentrations ($\mu g./10^6$ cells)			
				120	60	30	15
$AlPO_4$	2518	Crystal structure like quartz	Strong	+	Trace	0	0
$AlPO_4$	2507	Crystal structure like tridymite	Strong	+	Trace	0	0
$FePO_4$	2267	Crystal structure like quartz	None	Trace	0	0	0
Alumina (HX1010 heated to 820° C. for 1 hr.)	1342	γ-alumina	Strong	**+±***	+	Trace	0
Alumina (HX1010 heated to 1220° C. for 5 hr.)	1336	α-alumina	Weak	Trace	0	0	0
CaF_2	2996	Fluorspar	Weak†	+++	**++**	Trace	0

*Figures in bold type are the titration end-points.
†Policard and Collet (1952) found considerable activity *in vivo*.

TABLE 6
PROTECTION OF EXUDATE CELL CULTURES BY POTASSIUM ALUM AGAINST TOXIC EFFECT OF SILICA AS TRIDYMITE

Final Concentration of $KAl(SO_4)_2 \times 10^{-5}$ M	Equivalent Al Concentration (μg./10^6 cells)	Toxic Effect with Given Tridymite Concentrations (μg./10^6 cells)			
		30	15	7·5	Nil.
Nil	Nil	+++	+++	+±	.
4·25	0·5	+++	++	+	0
8·5	1	+±	+±	+	0
17	2	++	+±	Trace	0
34	4	++	+	Trace	0
68	8	+++	+	+	Trace

fibrogenic activity reported for the same dusts *in vivo*.

Inhibition of Silica Toxicity.—Experiments of the type shown in Table 6 were set up in which different concentrations of silica (tridymite 2612) were added to leucocyte cultures along with varying amounts of a potential antagonist. Antagonists were used in concentrations found by preliminary experiment to have little or no effect themselves on the cells. The most potent of those examined was potassium aluminium sulphate which protected cells very considerably against the effect of silica, presumably by virtue of aluminium hydroxide formed at the *p*H of the culture medium (7·2 – 7·4). Alumina HX 1010 (unheated), the preparation used by Gardner, Dworski, and Delahant (1944) to depress silica activity *in vivo*, provided only a slight degree of protection in tissue culture. A mixture of aluminium metal dust and alumina was very slightly more protective than alumina alone. Iron in the form of ferric chloride had a weak protective effect against silica, not greater than that of alumina. Mica and felspar dusts were also slightly protective but kaolin was not. The concentrations used of these three dusts were 30, 15, and 7·5 μg. per 10^6 cells respectively, the highest possible concentrations without causing confusion by their own toxicity.

Discussion

The relative toxicity of different forms of silica to leucocytes in tissue culture found in the present work agreed well with their pathogenicity and fibrogenic qualities *in vivo* as described by Gardner (1938) and by King and others (1953b). The high toxicity of cristobalite found *in vitro* is of interest since this type of silica has been reported to be responsible for a particularly severe form of silicosis in man (Vigliani and Mottura, 1948). Fairly close agreement was also found between the toxicity in tissue culture and the effects *in vivo* of aluminium and ferric phosphate and alumina heated to different degrees reported by King. King has found calcium fluoride weakly fibrogenic but the tissue culture results accord better with those of Policard and Collet (1953) who found calcium fluoride as pathogenic as quartz when injected intraperitoneally into rats. Coal dust which is relatively harmless *in vivo* had little effect on leucocyte cultures unless the cells were grossly overloaded with it. No clear difference related to type of coal could be demonstrated.

It appears probable from the correlation now demonstrated between fibrogenic activity and toxicity to leucocytes that injury to the phagocytic cell by dust is the stimulus for fibrous tissue formation in pneumoconiosis. In the intact animal this stimulus is presumably maintained for long periods by the continuous recruitment of fresh macrophages replacing those that die. In addition, no doubt, many of the cells containing low concentrations of dust survive for considerable periods during which time they might suffer damage and promote fibrosis.

The inhibition of silica toxicity by alumina in animals reported by Gardner and others (1944) and that by iron reported by Kettle (1932) have been reproduced in tissue culture although in neither case was the protection *in vitro* striking. However, the concentrations of iron used in the present work (10^{-3} to 10^{-4} M) are difficult to compare with those used by Kettle who coated silica particles with two-thirds of their weight of iron oxide. Gardner found great differences between the protective powers of different batches of alumina and it is possible that his most potent sample, HX 1010, which was used in the present work, has deteriorated. In contrast to the relatively weak actions of alumina and iron, considerable protection against silica toxicity was afforded to leucocytes by potassium alum, no doubt by means of aluminium hydroxide formed in the culture medium. The toxicity of silica was also found to be reduced in tissue culture by felspar and mica dusts, recalling the unexpectedly slight effect *in vivo* of quartz accompanied by these minerals in the form of granite as reported by Gardner (1938) and King, Ray, Harrison, and Nagelschmidt (1950).

The silicates, particularly kaolin and felspar, produced effects *in vitro* for which there have been no clear-cut equivalents *in vivo*. In experimental

animals the silicates produce far less fibrosis than does quartz (Cummins, 1937; King, Harrison, and Nagelschmidt, 1948; Mohanty, Roberts, King, Harrison, and Nagelschmidt, 1953). However, the published experimental work is not altogether consistent. For example, Kettle (1932) produced necrotic lesions in mice by the subcutaneous injection of kaolin, and Rüttner, Bovet, Weber, and Willy (1952) fibrous nodules by intraperitoneal injection. Mica was found lethal to phagocytes by Lemon and Higgins (1935) and by Policard (1934). A complicating factor has been introduced by the observation of Belt and King (1945) and King, Gilchrist, and Rae (1947) that the fibrogenic activity of mica was greatly increased if the dust had been treated with acid. This finding suggests that the effect of silicates in tissue culture may have depended to some extent on the experimental conditions and that investigation into the influence of these would be desirable.

It is not intended to suggest on the basis of the present work that tissue culture could be used to estimate the fibrogenic activity of different dusts. A much more comprehensive investigation than the present one would be necessary to define the utility of the technique in this respect. It does appear, however, that the rapidity and sensitivity of the quantitative tissue culture technique described above should make it useful for screening substances for protective action against dust toxicity and for investigating the mechanism of such toxicity. In the latter case a useful line of approach would appear to be the physical and chemical modification of the surface of dust particles, and a biochemical study of the mechanism of cell damage. The difference between the biological effects of tridymite and cristobalite on one hand and quartz and vitreous silica on the other requires investigation in this manner, as does the augmenting action of fluorine etching on the pathogenicity of quartz (King and others, 1953c).

Summary

A fairly close agreement was found between the toxicity to leucocytes *in vitro* of a number of dusts of interest in the field of pneumoconiosis and their fibrogenic activity as reported by other workers. Silicates proved more toxic in tissue culture, however, than experiments on animals would have suggested. Silica toxicity to leucocytes *in vitro* is antagonized by certain aluminium compounds.

We are indebted to Professor J. Gough for helpful comments on the paper.

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A QUANTITATIVE TECHNIQUE FOR STUDYING THE EFFECT OF DUST ON PHAGOCYTIC CELLS *IN VITRO*

BY

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Tissue culture techniques have so far contributed little to pneumoconiosis research, possibly because they have not permitted a quantitative assessment of toxicity. The method now presented attempts to remedy this deficiency. A single sample of tridymite, which *in vivo* is one of the most fibrogenic forms of silica, was used in all the experiments described below. An investigation into the effect of other types of dust using the same methods will be reported elsewhere.

The Technique in Outline

Exudates were induced in guinea-pigs by injecting 12 ml. of liquid paraffin intraperitoneally under ether anaesthesia. After 48 or, more usually, 72 hours the guinea-pig was killed by a blow on the neck and the peritoneal cavity washed out with Tyrode's solution. The cell suspension was freed from liquid paraffin by means of a separating funnel and a total and differential cell count made. The suspension was then centrifuged lightly, the supernatant fluid discarded, and the deposit re-suspended in tissue culture medium. The medium consisted of Tyrode's solution, sufficient guinea-pig and horse serum to give 12·5% of each after all additions, and streptomycin at a final concentration of 5 μg. per ml. Dust was introduced into cultures by adding a standard volume of a suspension in Ringer's solution to individual chambers. The volume used was 0·06 ml. delivered as 3 drops from a calibrated dropping pipette, care being taken to keep the dust evenly suspended during the operation. The chambers were cylindrical bottles incubated on their sides on an exactly horizontal surface. Rolling was prevented by stacking them in a box standing on its side. Cultures were incubated for three days at 37° C. and were not disturbed during this period for inspection or any other purpose. Each consisted of 2×10^6 cells in 1 ml. of medium. About 30 chambers were accommodated in a sealed 3-litre jar at the bottom of which 25 ml. of 1% sodium chloride was placed. An atmosphere of air plus 5% CO_2 was used and, to permit gaseous interchange, the liners were removed from the screw-caps of the bottles and the caps left loose. Since macrophages in tissue culture change their appearance on cooling, they were examined without delay after removal from the incubator. Rotation of the bottles to bring the lower surface of the chamber uppermost allowed microscopical examination of the cells adhering to the glass with a 2/3 in. objective. Removal of the medium was not necessary. Some minutes were available before the cells showed signs of suffering from their exposure.

Details of the technique outlined above are given in the following sections together with experimental evidence in favour of certain of the procedures recommended.

Details of Technique

Culture Chamber.—The success of the method depends on the use of a chamber with a concave inferior surface on to which cells and dust gravitate. Such an arrangement appears greatly to favour an even distribution of the dust and cells and uniform phagocytosis throughout the culture. In our earlier experiments they were allowed to settle on to a plane surface but a regular distribution could not then be ensured. The bottle used as the culture chamber was cylindrical, approximately 50 mm. long and 20 mm. in diameter, with a capacity of 14·5 ml. It was made of thin neutral glass and fitted with a metal screw cap.*

New bottles and their caps were boiled in sodium oleate solution, rinsed, boiled twice in tap water, and finally once in distilled water. The cap liners were discarded. Cleansing after use was similar except for an extra preliminary boiling in oleate solution followed by vigorous brushing. Chambers were sterilized in the autoclave with their lids loose and dried off at 37° C. When they had been used about six times, the bottles were treated with acid dichromate for three days after their usual cleansing. They were subsequently washed meticulously, soaked in several changes of tap water over a period of some days, and finally left overnight in distilled water before being returned to use.

The Cell Population.—In the great majority of exudates,

*This bottle, designated the Sanders neutral vial, is obtainable from Messrs. S. H. Travis & Co. We are indebted to Dr. F. K. Sanders for bringing it to our notice.

between 70 and 90% of the cells were mononuclear and the remainder polymorphonuclear. If the proportion of polymorphs exceeded 40% cultures were likely to be unsatisfactory. An excessive proportion of polymorphs was obtained when an attempt was made to use light liquid paraffin which is easier to inject than the ordinary kind. The mononuclear cells consisted of macrophages, often containing liquid paraffin, cells resembling blood monocytes, and small cells with scanty cytoplasm whose nature was uncertain. Polymorphs rapidly disappeared from cultures but the fate of the different types of mononuclear cell could not be distinguished. With knowledge on this point standardization of the cell inoculum might have been improved but in the event only the total cell count was standardized.

In the given experimental conditions, cell cultures were healthy only within certain limits of population density, corresponding approximately to inocula of between $0{\cdot}5 \times 10^6$ and 4×10^6 cells per chamber in 1 ml. of medium. The effect of different amounts of tridymite dust on cell populations of different size is shown in Table 1. The inoculum of $0{\cdot}25 \times 10^6$ cells was sub-optimal, controls without dust being less healthy than controls with larger inocula. The results show a close correlation between the degree of cell damage observed and the amount of dust available per cell. It was to be expected therefore that the effect of a given amount of dust would vary somewhat in different experiments according to the proportion of viable cells in the inoculum. The extent of the variation is shown in Table 2 which records titrations of the standard tridymite suspension in 20 experiments, each with a different cell donor. The same end-point was obtained in 13 titrations and a difference of one dilution in the remainder. When comparisons are to be made between the results of different experiments it appears advisable to include such a standard dust titration in each as a reference and as a check on experimental conditions.

TABLE 1

EFFECT OF TRIDYMITE DUST ON EXUDATE CELL CULTURES OF DIFFERENT POPULATION SIZE

Amount of Dust per Chamber (μg.)	Toxic Effect* with Given Inoculum of Cells per Chamber				
	4×10^6	2×10^6	1×10^6	$0{\cdot}5 \times 10^6$	$0{\cdot}25 \times 10^6$
30	+	++	+++	+++	+++
15	Trace	+	++	+++	+++
7·5	0	Trace	+	++	+++
3·75	0	0	0	Trace	+++

* See text for explanation of symbols.

Reading.—The normal undusted culture after three days' incubation contained very few cells which were not translucent and amoeboid in shape. The degree of elongation of the cells and their processes varied considerably with different cell donors and could not be used to estimate a toxic effect. However, loss of amoeboid shape accompanied by an increase in optical density and a decrease in the number of cells adherent to the glass was reliable evidence of cell damage. A very small proportion of the cells (considerably less than 0·1%) appeared not to phagocytose dust and to be unharmed in high concentrations of a toxic dust. Such resistant cells had the appearance of fibroblasts in tissue culture but may have been desquamated lining cells. They did not interfere with assessments of dust toxicity and no investigation was made into their nature or origin.

In undusted cultures the cells adherent to the glass were distributed in a characteristic manner. They were found over the entire floor of the chamber but were somewhat more numerous over the middle third of its length.

TABLE 2

EFFECT OF ONE SAMPLE OF TRIDYMITE IN 20 EXPERIMENTS EACH WITH DIFFERENT CELL DONOR

Amount of Dust per Chamber (μg.)	Toxic Effect in Each of 20 Experiments									
	1	2	3	4	5	6	7	8	9	10
60	+++	+++	·	·	+++	+++	+++	+++	+++	+++
30	++	+++	++	+++	++	+++	+++	++	++	+++
15	+	++	+	++	Trace	++	++	+	++	++
7·5	Trace	Trace	Trace	+	0	Trace	+	0	+	+
3·75	0	0	0	Trace	0	0	Trace	0	Trace	0

Amount of Dust per Chamber (μg.)	Toxic Effect in Each of 20 Experiments									
	11	12	13	14	15	16	17	18	19	20
60	+++	·	+++	+++	+++	+++	·	+++	++±	++±
30	+++	++	++	+++	+++	++	++	+++	++	++
15	++	+	Trace	++	++	++	++	++	++	++
7·5	Trace	Trace	0	+	+	+	+	++	Trace	Trace
3·75	0	0	0	Trace	Trace	Trace	Trace	+	0	0

The end-point in dust titrations (shown by heavy line) was determined by a degree of cell damage exceeding + (see text). A standard inoculum of 2×10^6 exudate cells per chamber was used throughout.

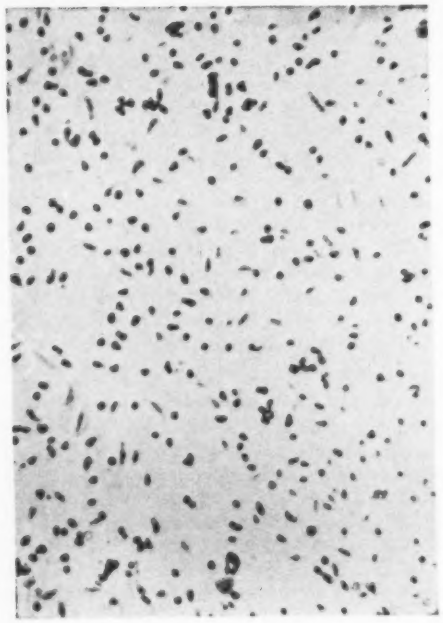

FIG. 1.—Normal exudate cell culture after three days' incubation, stained with haematoxylin and photographed through culture bottle. ×120.

FIG. 2.—Cell culture replicate of that in Fig. 1 but incubated with 15 μg. of tridymite dust X2612. ×120.

Transversely their distribution was fairly uniform over several millimetres. Where densest they were close to one another but not in contact.

It was found convenient to define the following three main degrees of cell damage :—

\+ Considerably fewer cells adhere to the glass than in the controls. They are optically denser and less active than normal cells, a large proportion having partially or completely rounded off.

\+ + Less than 10% of the cells remain on the glass. Most of the survivors are optically dense whether rounded off or not.

\+ + + Fewer than 50 cells remain. These may show signs of damage or be fibroblast-like cells apparently indifferent to dust.

It was often useful to recognize intermediate degrees of damage which were designated " trace ", + ± and + + ±.

To facilitate the comparison of different dusts or the effect of different conditions on the toxicity of a single dust, the method was adopted of determining the smallest amount of dust necessary to produce an arbitrary degree of cell damage, namely, damage greater than that designated +.

The appearance of an undusted three-day leucocyte culture is shown in Fig. 1. The effect of incubating a replicate culture with 15 μg. of tridymite X2612 is shown in Fig. 2. The degree of damage in the dusted culture was recorded as + +. Dusted cells are usually slightly larger than normal cells and in addition, owing to their greater optical density, their size is somewhat emphasized by photography.

Medium and Atmosphere.—Sterile Tyrode's solution was prepared aseptically from 25% glucose, 5% sodium bicarbonate, and a solution of the remaining constituents. These three solutions were autoclaved separately, the bicarbonate in sealed ampoules after saturating with CO_2. Cultures fared much better in medium containing homologous serum as compared with horse serum. However, equal parts of each proved satisfactory. (The horse serum was supplied filtered and unheated by the Serum Research Institute, Carshalton.) Final serum concentrations of 17%, 25%, and 40% were compared. The results with the two higher concentrations were similar and slightly superior to those with the lowest. Comparisons were made of sera from different donors and of sera stored at 4° C. for periods varying from two to 90 days. Neither variable appeared to influence the health of cultures.

The *p*H of serum-Tyrode solution was higher than the optimum for macrophages. A sufficiently large cell inoculum produced enough acid to make the *p*H favourable but not when dust reduced its vitality. This difficulty was avoided by adding CO_2 to the atmosphere. Concentrations of 2·5% and 5% CO_2 were equally satisfactory; 10% was slightly excessive. The choice was finally made of an atmosphere of 5% CO_2 in air.

Length of Incubation.—With the technique described above, full activity of the macrophage cultures was attained after two days' incubation and deterioration became apparent after five days, the medium not having been renewed. When the tridymite suspension was

titrated during different periods of incubation the arbitrary end-point changed from 30 μg. per ml. of culture after the first and second days to 15 μg. after the third and fourth and to 7·5 μg. after the fifth. The period of three days' incubation was chosen for standard practice as being long enough for the display of dust toxicity without risk of exhaustion of the medium.

Dust.—The sample of tridymite X2612 used in the present investigation had a specific surface of 2·2 m.^{2}/g. and a size distribution as follows:—

Diameter (μ)	< 0·23	0·23-	0·32-	0·45-	0·64-	0·9-	1·3-	1·8-	2·6-
Mass (%)	0·2	0·3	0·6	2·7	7·9	18·1	29·7	40·5	0

A stock suspension was made by suspending 40 mg. of the dust in 10 ml. of Ringer's solution and sterilized by heating in a boiling water-bath for 15 minutes. Its toxicity did not appear to change during three months' storage at 4° C. Dispersion of the dust was assisted by shaking mechanically before use.

Discussion

The chief applications of an experimental technique for studying the effect of dust would appear to be in estimating the hazards of exposure to different dusts, in examining protective agents, and in investigating the mechanism of dust toxicity. Animals have been used in such investigations with a certain degree of success but suffer from the disadvantage that observation over long periods of time is necessary. Studies on the mechanism of dust toxicity are difficult in the intact animal because the chief effects observed are not the primary damage to the phagocytic cells but the secondary vascular and connective tissue reactions. The technique described in the present work is perhaps more complex than that required for experiments on animals but gives results quickly and economically and permits direct observation of the effect of dust on the cells ingesting it. In a later communication it will be shown that in most respects its results are comparable with those obtained in intact animals.

Summary

A technique is described in which phagocytes and dust are allowed to settle together on to the concave floor of a tissue culture chamber which is reversed for direct microscopical observation after a few days' incubation. The toxicity of a dust may be titrated by determining the concentration necessary to produce a standard degree of cell damage.

We are indebted to Dr. G. Nagelschmidt, Safety in Mines Research Establishment, Sheffield, for the sample of tridymite X2612 and to Mr. C. A. Lediard for the photographs.

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THE USE OF A SIZE SELECTOR FOR DUST SAMPLING WITH THE THERMAL PRECIPITATOR

BY

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Ideally, in order to relate dust concentrations expressed in terms of one parameter, *e.g.*, number per unit volume, with those expressed in terms of another parameter, *e.g.*, mass per unit volume, the particles counted by microscope in a thermal precipitator sample should be within the same size range as samples collected by other means for the determination of mass concentration.

It is generally agreed that dust particles in order to produce pneumoconiosis must usually be less than 5 μ in size, that is to say, that their terminal velocities must be less than that of a sphere of unit density and diameter 5μ. For gravimetric determinations of such dust particles, the sampling instrument is now usually fitted with a size selector, working on aerodynamic principles, designed to have a collecting efficiency of 50% for 5 μ particles. (It is, of course, not possible to make a size selector with a sharp cut-off at these small sizes.) Existing practice, on the other hand, involves microscopic counting with the aid of a graticule and makes an arbitrary 100% cut-off visually at a mean cross-sectional diameter of 5 μ. This may or may not be almost identical in its outcome with the result obtained with a terminal velocity cut-off.

An investigation has been carried out to compare counts of particles, 1 to 5 μ in diameter, obtained by normal thermal precipitator practice with those obtained when a suitable size selector was fitted to the instrument and counts were made of all particles greater than 1 μ in diameter.

Sampling Procedure

The size selector used (Fig. 2) was that developed for use with the thermal precipitator by the National Coal Board Central Research Establishment (Hamilton and Walton, 1952). When the sampling rate is 7 cu. cm. /min. this selector has the characteristic shown in Fig. 1. It can be attached to the top of a thermal precipitator head by means of the gauze filter cap after the gauze screen has been removed. When the selector is in position the face with two slots is uppermost and the slots are parallel

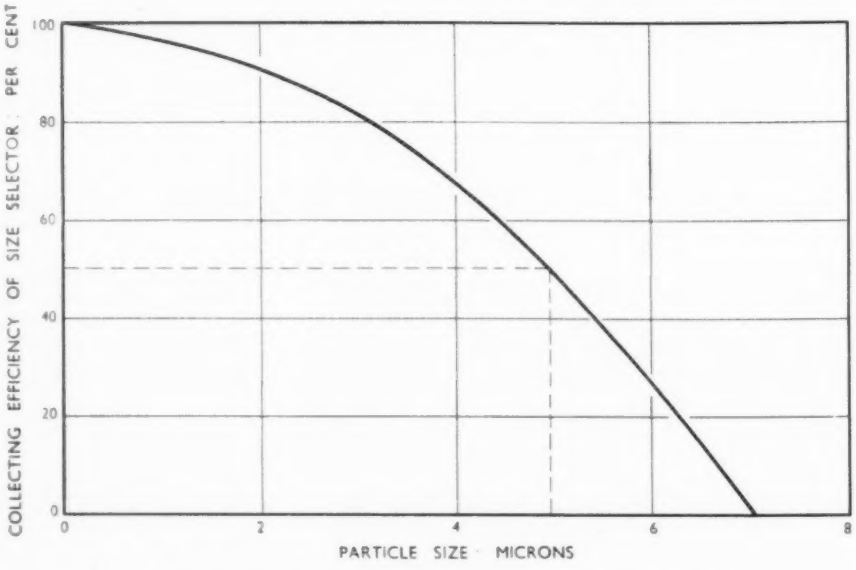

FIG. 1.—Collecting characteristic of size selector. [*Crown copyright S.M.R.E.*

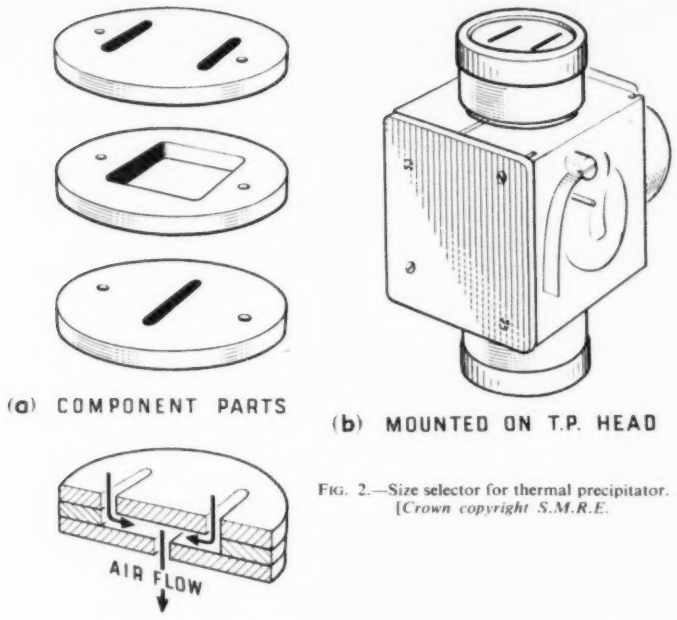

FIG. 2.—Size selector for thermal precipitator.
[*Crown copyright S.M.R.E.*

with the channel giving entry to the head of the thermal precipitator.

With this device attached to one thermal precipitator only, simultaneous samples were taken (at the rate of 7 cu. cm./min.) with two thermal precipitators in a number of different environments in coal-mines throughout the country. As many pairs of samples as possible were taken during a working shift, up to a maximum of 15 pairs; in no case was the number of pairs less than five. In addition, when the main sampling site was on the working face, a similar number of pairs of samples was taken 10 yards down the return airway. During sampling the size selector was changed from one precipitator to the other for alternate samples, and after every second sample the positions of the two thermal precipitators were exchanged.

Environments Sampled

Sampling was carried out in all the different coalfields in Great Britain during a variety of different mining operations, including the cutting of coal, the getting of coal by pneumatic picks, hand-filling operations, cutter-loading operations, belt-loading operations, and drilling operations in a hard heading. In this way, most of the dust-producing operations encountered in coal-mines were investigated and whatever differences there might be in the size distribution of dust clouds so produced would be taken into account.

Evaluation of Samples

The samples were counted and sized so as (*a*) to compare the total counts of all particles greater than 1 μ diameter in those samples taken by a thermal precipitator fitted with a size selector with the counts of particles 1 to 5 μ diameter in corresponding samples taken with a standard thermal precipitator, and (*b*) to compare the size distributions in the corresponding pairs of samples in the size ranges 0·5 to 1, 1 to 2·5, 2·5 to 5, 5 to 10, and 10 to 25 μ.

In these evaluations, aggregates of particles were counted as one particle where they could not visually be divided into two or more separate entities. This is now the generally accepted procedure.

Discussion of Results

Lack of space precludes the reproduction of all the results either in tabular form or as curves and diagrams.* Some typical diagrams are given to illustrate the general conclusions.

Two forms of elementary analysis were formed on the data collected.

(1) The ratio was obtained, for each pair of samples, of the number of particles per cc. in the size range greater than 1 μ as measured by the thermal precipitator fitted with a size selector to the number of particles per cc. in the size range 1 to 5 μ as measured by the standard thermal precipitator. When the distributions of this ratio for the different sampling positions were compared there was no significant difference between them (see Appendix). This negative result may, to some extent, be due to the statistically small size of the sample of the distribution of the ratio for a given sampling position, but it implies that the distributions may legitimately be combined where they were obtained at sampling positions of like kind.

The combined distribution for different types of sampling situations is shown in Fig. 3. As is not unexpected, the distribution is approximately log normal. It indicates that the mean value of the ratio is of the order unity. If any bias exists it is such as to suggest that the ratio is greater than unity rather than less.

It is clearly desirable to have an estimate of the experimental error so that the dispersion of the values of the ratio shown in Fig. 3 can be examined critically. Ideally, such an estimate would have been obtained by comparing two standard thermal precipitators (neither being fitted with a size selector) in the same clouds as those sampled in the investigation. However, to limit the labour involved in the

* The full tables are available upon request to the authors at the Safety in Mines Research Establishment, Portobello Street, Sheffield, 1.

Brit. J. industr. Med., 1956, **13**, 196.

THE USE OF A SIZE SELECTOR FOR DUST SAMPLING WITH THE THERMAL PRECIPITATOR

BY

J. T. BURDEKIN and J. G. DAWES

From the Safety in Mines Research Establishment, Ministry of Fuel and Power, Sheffield

(RECEIVED FOR PUBLICATION NOVEMBER 16, 1954)

Ideally, in order to relate dust concentrations expressed in terms of one parameter, *e.g.*, number per unit volume, with those expressed in terms of another parameter, *e.g.*, mass per unit volume, the particles counted by microscope in a thermal precipitator sample should be within the same size range as samples collected by other means for the determination of mass concentration.

It is generally agreed that dust particles in order to produce pneumoconiosis must usually be less than 5 μ in size, that is to say, that their terminal velocities must be less than that of a sphere of unit density and diameter 5μ. For gravimetric determinations of such dust particles, the sampling instrument is now usually fitted with a size selector, working on aerodynamic principles, designed to have a collecting efficiency of 50% for 5 μ particles. (It is, of course, not possible to make a size selector with a sharp cut-off at these small sizes.) Existing practice, on the other hand, involves microscopic counting with the aid of a graticule and makes an arbitrary 100% cut-off visually at a mean cross-sectional diameter of 5 μ. This may or may not be almost identical in its outcome with the result obtained with a terminal velocity cut-off.

An investigation has been carried out to compare counts of particles, 1 to 5 μ in diameter, obtained by normal thermal precipitator practice with those obtained when a suitable size selector was fitted to the instrument and counts were made of all particles greater than 1 μ in diameter.

Sampling Procedure

The size selector used (Fig. 2) was that developed for use with the thermal precipitator by the National Coal Board Central Research Establishment (Hamilton and Walton, 1952). When the sampling rate is 7 cu. cm./min. this selector has the characteristic shown in Fig. 1. It can be attached to the top of a thermal precipitator head by means of the gauze filter cap after the gauze screen has been removed. When the selector is in position the face with two slots is uppermost and the slots are parallel

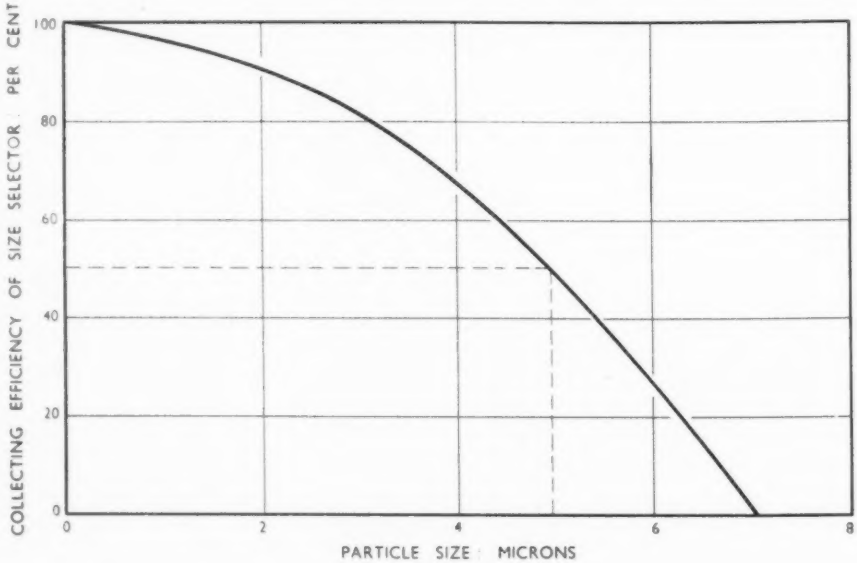

FIG. 1.—Collecting characteristic of size selector. [*Crown copyright S.M.R.E.*

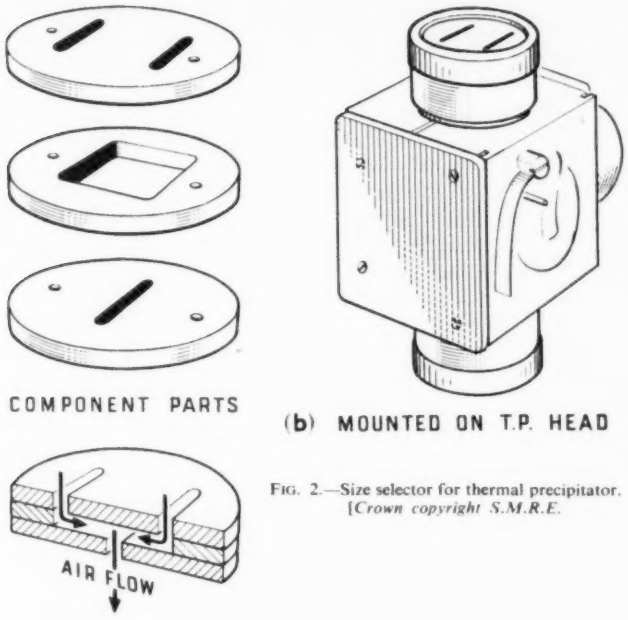

FIG. 2.—Size selector for thermal precipitator.
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with the channel giving entry to the head of the thermal precipitator.

With this device attached to one thermal precipitator only, simultaneous samples were taken (at the rate of 7 cu. cm./min.) with two thermal precipitators in a number of different environments in coal-mines throughout the country. As many pairs of samples as possible were taken during a working shift, up to a maximum of 15 pairs; in no case was the number of pairs less than five. In addition, when the main sampling site was on the working face, a similar number of pairs of samples was taken 10 yards down the return airway. During sampling the size selector was changed from one precipitator to the other for alternate samples, and after every second sample the positions of the two thermal precipitators were exchanged.

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The samples were counted and sized so as (*a*) to compare the total counts of all particles greater than 1 μ diameter in those samples taken by a thermal precipitator fitted with a size selector with the counts of particles 1 to 5 μ diameter in corresponding samples taken with a standard thermal precipitator, and (*b*) to compare the size distributions in the corresponding pairs of samples in the size ranges 0·5 to 1, 1 to 2·5, 2·5 to 5, 5 to 10, and 10 to 25 μ.

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It is clearly desirable to have an estimate of the experimental error so that the dispersion of the values of the ratio shown in Fig. 3 can be examined critically. Ideally, such an estimate would have been obtained by comparing two standard thermal precipitators (neither being fitted with a size selector) in the same clouds as those sampled in the investigation. However, to limit the labour involved in the

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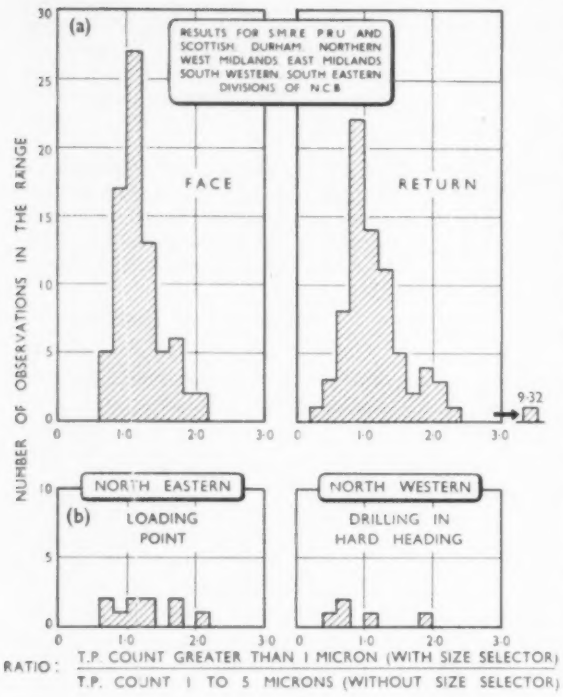
(a)
RESULTS FOR SMRE PRU AND SCOTTISH, DURHAM, NORTHERN, WEST MIDLANDS, EAST MIDLANDS, SOUTH WESTERN, SOUTH EASTERN DIVISIONS OF N.C.B.
FACE
RETURN
9·32
NUMBER OF OBSERVATIONS IN THE RANGE
(b)
NORTH EASTERN
LOADING POINT
NORTH WESTERN
DRILLING IN HARD HEADING
RATIO: T.P. COUNT GREATER THAN 1 MICRON (WITH SIZE SELECTOR) / T.P. COUNT 1 TO 5 MICRONS (WITHOUT SIZE SELECTOR)

FIG. 3.—Ratio of thermal precipitator counts with and without size selector. [*Crown copyright, S.M.R.E.*

trial itself, this was not done, so that directly comparable data are not available; but an estimate of the order of magnitude of the experimental error can be obtained from previous work by the Safety in Mines Research Establishment on surveys in return roadways during filling shifts. Fig. 4 shows a histogram obtained from the results of this work by plotting the ratio of the concentrations as measured by two standard thermal precipitators when sampling the same cloud simultaneously. It is seen that the dispersal of the values of the ratio shown in Fig. 4 is similar to that given in Fig. 3. This strengthens the view, therefore, that on the average, due allowance having now been made for experimental error, the count in the size range greater than 1 μ obtained from a thermal precipitator fitted with a size selector is equal to, or somewhat greater than, the conventional count (in the size range 1 to 5 μ) taken with an ordinary thermal precipitator.

(2) The alternative method of testing the equivalence of the two counts is to examine the regression zones established by plotting the counts one against the other. Typical scatter diagrams are shown in Fig. 5. There are two main types. The first type (Fig. 5a) shows the observations to be evenly scattered about the line of perfect agreement, and is typical of the data obtained by four N.C.B. divisions and by the Pneumoconiosis Research Unit. With the second type (Fig. 5b), the indication is that the values of the count greater than 1 μ with the thermal precipitator fitted with a size selector are somewhat greater than the counts 1 to 5 μ obtained with the standard thermal precipitator. When the ratio was somewhat greater than unity, the samples were taken in clouds of higher concentration. Fig. 5b is typical of results obtained by three N.C.B. divisions and by the Safety in Mines Research Establishment. In addition, a third type of scatter diagram was obtained from data presented by two other N.C.B. divisions in which the observations, like those in Fig. 5a, are relatively evenly distributed about the line of perfect agreement; but they are few in number, the range of concentrations sampled is low and, in general, the dust concentrations themselves were low. To help in the assessment of the scatter diagrams, the previously mentioned data, obtained with two standard thermal precipitators sampling the same cloud simultaneously, are plotted in Fig. 6. This illustrates the

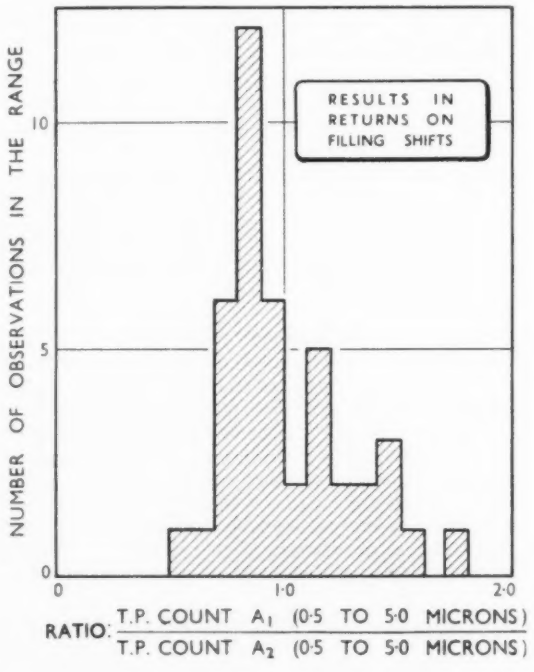
RESULTS IN RETURNS ON FILLING SHIFTS
NUMBER OF OBSERVATIONS IN THE RANGE
RATIO: T.P. COUNT A_1 (0·5 TO 5·0 MICRONS) / T.P. COUNT A_2 (0·5 TO 5·0 MICRONS)

FIG. 4.—Ratio of counts with two standard thermal precipitators. [*Crown copyright, S.M.R.E.*

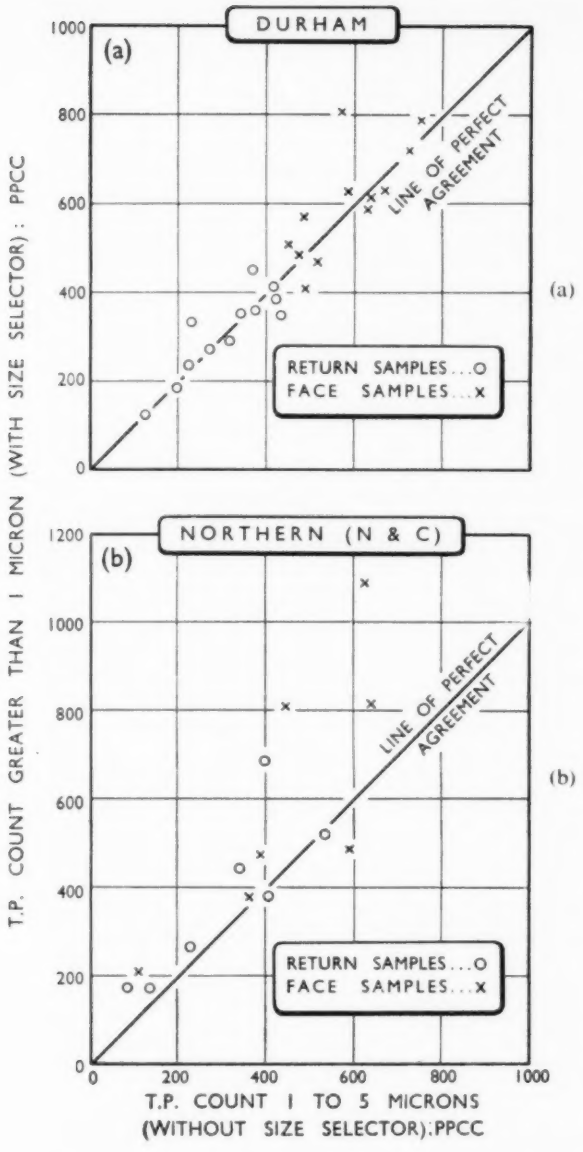

FIG. 5.—Typical examples of relationships between counts with and without size selector. [*Crown copyright, S.M.R.E.*

magnitude of the experimental errors to be expected in this type of investigation.

Comparison of Fig. 5a and Fig. 6 suggests that there is no reason to suppose that the scatter of the observations about the line of perfect agreement for the Durham data is due to other than experimental error (see also Appendix). This was also the case for the data received from the Pneumoconiosis Research Unit and from five other N.C.B. divisions.

The bias shown in Fig. 5b is not readily explained. The count of particles greater than 1 μ from a thermal precipitator fitted with a size selector is larger than the count 1 to 5 μ from the standard thermal precipitator. In all the cases typified by Fig. 5b (there were four other cases) sampling had taken place in high concentrations and the bias may be due to the behaviour of the size selector when it is called upon to eliminate large numbers of coarse particles. When the size selection characteristics of the horizontal elutriator system were determined for each pair of samples, it was noted that in two of the N.C.B. divisions giving scatter diagrams like Fig. 5b, namely Scotland and South Wales, the size selection characteristics were anomalous. Both the face and return samples from South Wales showed a negligible size selection effect as did the face samples in Scotland, though the characteristics for the return samples from Scotland were normal. This effect may be caused by the presence of a large quantity of coarse airborne dust, though the phenomenon needs further investigation.

To summarize the discussion, the results displayed in Fig. 3 and typified by Fig. 5, suggest that there is equivalence within experimental error between the

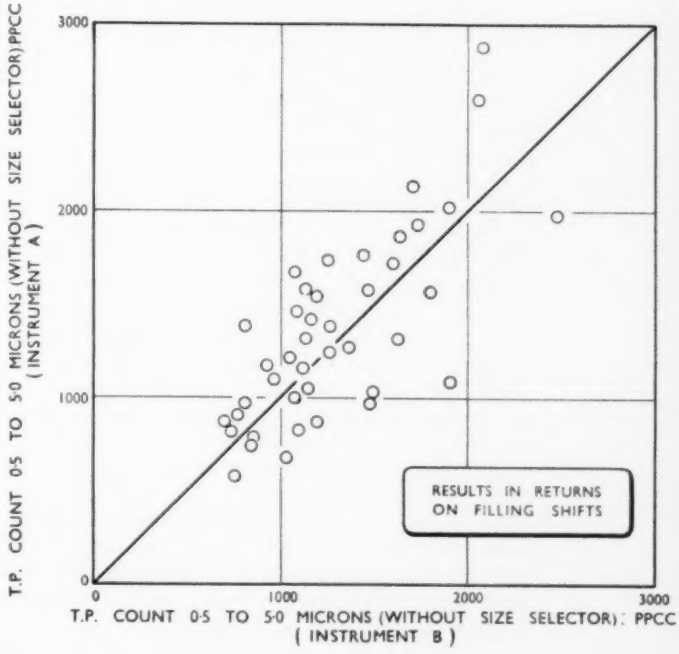
RESULTS IN RETURNS ON FILLING SHIFTS
T.P. COUNT 0·5 TO 5·0 MICRONS (WITHOUT SIZE SELECTOR): PPCC (INSTRUMENT A)
T.P. COUNT 0·5 TO 5·0 MICRONS (WITHOUT SIZE SELECTOR): PPCC (INSTRUMENT B)
0
1000
2000
3000

FIG. 6.—Comparison of counts on two standard thermal precipitators. [*Crown copyright, S.M.R.E.*

count in the size range 1 to 5 μ from a standard thermal precipitator and the count in the range greater than 1 μ from a sample taken through a size selector of the type tested. There were some exceptions, all similar to one another, which showed a larger count (in the range greater than 1 μ) when the size selector was used than was obtained by the conventional method without a size selector in the size range 1 to 5 μ. The exceptional results may possibly be accounted for by the fact that in these instances heavy concentrations were being sampled with the result that the size selectors tended to become choked with coarse dust.

Thus, while it is more satisfying theoretically if a sampling instrument reproduces the size selection characteristic of the human lung, the results already discussed suggest that the use of a size selector is not essential in sampling with a thermal precipitator. The counts obtained in the normal way for the particles 1 to 5 μ in size were equivalent to those in the size range greater than 1 μ when a size selector is used.

Nor, in the main, did the investigators taking part find that the process of counting had been made easier by the use of the size selector, for seven out of 10 of those who evaluated the samples said that it was not. One investigator stated that although counting was made easier, this facility did not outweigh the disadvantage caused by having to clean the selector between successive samples. This may be necessary if low-pressure constant-head aspirators of the type developed at the Safety in Mines Research Establishment (Dawes, Howarth, and Slack, 1954) come into use. However, with minor modifications, it is possible to increase the capacity of the size selector, for example, by providing a small recess in the bottom plate beneath the entrance channels, and this may avoid the necessity for repeated cleaning.

At first sight, the fact that counting was not made easier when the selector was used appears to be an unexpected finding. The reason may be that most of the difficulty in size determination is met at the lower sizes and in this investigation discrimination had to be made between particles above and below 1 μ in size whether the selector had been used or not. At the top end of the size scale (5 μ) the difficulty of discrimination would not be so great because of the increased size of the particle in view and also because the number of particles over that size would be relatively small, even in samples taken without the use of the selector.

All these several points, coupled with the fact that the use of the selector causes a loss of information about the size distribution in the range up to 10 μ, suggest that for ordinary purposes there is no advantage to be gained by fitting a size selector. On the other hand, its use would almost certainly facilitate the evaluation of samples by automatic machines, because some of the discrimination between particles carried out by such machines will already have been made by the selector.

The use of a size selector might also have two other possible advantages: it should enable sampling to proceed for longer periods in clouds with many coarse particles without particles on the sample overlapping; it should also reduce the interference caused when large particles adhere to the hot wire.

Summary

The experiments described in this report were necessary in order to increase our knowledge of the parameter of dust concentration actually measured when airborne dust clouds are sampled by the standard thermal precipitator. It was not known to what extent this parameter was related to the aerodynamic or lung-penetrating properties of the dust particles. An estimate of this relationship has been obtained by the use of a size selector, working on aerodynamic principles, in conjunction with one thermal precipitator, and comparing the results so obtained with those given by an unmodified thermal precipitator.

The results have shown that the present count in the size range 1 to 5 μ with a standard thermal precipitator is a satisfactory measure of the dust-cloud concentration; it is not significantly different from the theoretically more satisfying convention of the count greater than 1 μ obtained with a thermal precipitator fitted with a size selector.

In consequence, and in the absence of other substantial advantages, it is not considered desirable to recommend that the size selector should always be used in a thermal precipitator sampling in airborne clouds in British coal-mines.

The work was carried out on behalf of Panel I of the Sub-Committee on Dust, a sub-committee of the Medical Research Council's Committee on Industrial Pulmonary Diseases. The authors' thanks are due to the Sub-Committee and to the Ministry of Fuel and Power for permission to publish this paper. Valuable assistance in the arrangements for the underground experimental work was given by Mr. W. H. Walton and Mr. F. Henley Price of the National Coal Board Scientific Staff and by Mr. S. Roach of the Pneumoconiosis Research Unit of the Medical Research Council.

Thanks are also due to the many individuals who carried out the sampling in mines throughout the country and to those who evaluated the samples.

APPENDIX

The data obtained in any given category were relatively sparse. It was not profitable therefore to carry out statistical tests aimed at great precision. It was, however, worth while to establish that there was no evidence in the data which suggested that it was not legitimate to amalgamate the data from different sampling positions of a given type. Thus, when the distributions of the ratio of the count with the size selector to the count when the size selector was not used at the different sampling positions were compared by the Student t test, there was no indication at the 5% significance level that the distributions were samples from different populations. Accordingly, the data were combined as shown in Fig. 3 and the resulting distributions may be taken as representative of the overall populations of the ratio at the different types of sampling position. There is no significant difference between the populations of the ratio obtained at the different sampling positions. The data given in Fig. 4 are not strictly comparable with the present results (see also below), because the two standard thermal precipitators were sampling in clouds different from those used in the size selector tests, and also because the counts in the size range 0·5 to 5 μ (instead of 1 to 5 μ) were recorded. Nevertheless, the data can be used to estimate the order of magnitude of the "experimental" error. When the distributions of Fig. 3 and Fig. 4 are compared, the distributions are found to be not significantly different at the 5% level.

Again, although the data are not strictly comparable, it is instructive to compare the correlation of the observations of the count with the size selector to the count (in the restricted range 1 to 5 μ) when no size selector was fitted for the samples from the Durham and Northern (N. & C.) Divisions with the correlation between the results given by two thermal precipitators when neither is fitted with a size selector and they are sampling simultaneously.

For this purpose, since inspection of Figs. 5 and 6 suggests that the scatter of observations is proportional to the level of the dust-cloud concentrations, the data were transformed logarithmically. As a result the regression zone obtained with the transformed variables become, in effect, constant in width, and a linear regression analysis was carried out. In Table 1, σ_1 is the residual standard deviation of the scatter (obtained with the transformed variable) when, for the size selector trials, the count without the selector was taken as the independent variable, and σ_2 the residual standard deviation when the count with the size selector was taken as the independent variable. In the experiments with two standard thermal precipitators, σ_1 and σ_2 were obtained by considering the count first from one thermal precipitator and then from the other as the independent variable.

Origin of Data	Comparison	Number of Pairs of Observations	Correlation Coefficients	Residual Standard Deviation about Regression Line (logarithmic units)	
				σ_1	σ_2
S.M.R.E. Fig. 6	Two standard thermal precipitators	42	0·73	0·095	0·110
Durham Division Fig. 5a	Thermal precipitator with size selector and one with no size selector fitted	24	0·92	0·078	0·097
Northern (N. & C.) Division Fig. 5b	do.	14	0·91	0·113	0·120

On this basis, the scatter of the observations from Durham is somewhat less, while that for the Northern (N. & C.) Division is somewhat greater than that obtained with thermal precipitators on which size selectors were not fitted. There is no evidence, therefore, that the scatter of the results about the line of perfect agreement, when results with and without the size selector are compared, is due to anything other than experimental error.

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Brit. J. industr. Med., 1956, **13**, 202.

THE USE OF THE PULHEEMS SYSTEM OF MEDICAL CLASSIFICATION IN CIVILIAN PRACTICE

BY

M. D. WARREN

From the London County Council

(RECEIVED FOR PUBLICATION FEBRUARY 6, 1956)

In 1948 the three Armed Services adopted the Pulheems system of medical classification. Since then it has been suggested that such a system would be of benefit in industry (Fletcher, 1949; Lewis, 1952). This paper studies the results obtained from applying the Pulheems system to 1,000 applicants for civilian employment.

The Pulheems System

The Pulheems system, described in detail by Fletcher (1949) and in various official Service publications, consists of an assessment of seven different " qualities " designated as follows :—

P = Physical capacity including physique, general medical condition, and any systematic disease
U = Upper limbs, considered functionally
L = Locomotion, also considered functionally
H = Hearing measured as follows :—

H1 is ability to hear a forced whisper at 20 feet in each ear separately; H2 can hear forced whisper at 10 feet in each ear separately; H3 can hear forced whisper with both ears together at 10 feet ; and H7 can hear the conversational voice at 10 feet with both ears.

EE is visual acuity of the right and left eye respectively. E1 is equivalent to Snellen 6/6, E2 to 6/9, E3 to 6/12, E4 to 6/18, E5 to 6/24, E6 to 6/36, E7 to 6/60, and E8 is less than 6/60.

M is mental capacity (intelligence), which is not usually measured by the medical officer.

S is emotional stability, assessed particularly by reference to past history.

Each quality is given a number. For P and EE this may be any number from 1 to 8, but U, L, and H can only be 1, 2, 3, 7, or 8, whilst M and S can only be 2, 3, 7, or 8. The number (or degree) represents the functional capacity of the quality. Degrees 1 and 4 imply functional efficiency above the average. The average is represented by degrees 2 and 5, and 3 and 6 imply below-average functional efficiency. Degrees 1 to 3 allow employment anywhere in the world, but 4 to 6 limit employment to temperate climates only. Degree 7 for any quality designates fitness for home service only and 8 means unfitness for any form of military service. These degrees are assessed on a functional basis and, to quote the document which introduced the Pulheems system to the Services, " the anatomical lesion should not in any way form the basis of classification ". The more precise instructions do not entirely follow this ideal; thus they state: " Evidence of mitral or aortic incompetence is a reason for placing in P8." and " Active pulmonary tuberculosis or evidence that the disease has been active within the past five years places a man in P8 ". . . " Mild, non-incapacitating asthma will limit to P6 ".

As far as possible in this survey, the strict military interpretation has been used. There would be no value in the widespread adoption of the Pulheems system for civilian use if each undertaking had its own interpretations and gradings.

The Present Investigation

Starting on January 1, 1955, after a previous short trial to ascertain the best method of recording the findings, each applicant presenting for pre-employment medical examination was given a Pulheems category (or profile). The first 600 men and 400 women seen were taken. No other selection was made.

The age, sex, and occupational grouping of these 1,000 people are shown in Table 1. Altogether there were 73 occupations (excluding different ranks within an occupation). The types of employment that have been grouped together are " teachers ", including teachers, teacher-trainees, and physical training instructors; " firemen and ambulance drivers ", who include ambulance attendants; " clerical and social workers " includes administrative and clerical staff, nurses, health visitors, mid-

wives, doctors, solicitors, architects, engineers, and other professional workers; " other " includes park keepers, gardeners, building trade operatives, messengers, porters, warehousemen, laundry women, drivers, cooks and domestics, cleaners, schoolkeepers, school inquiry officers, and unskilled labourers.

TABLE 1
AGE, SEX, AND OCCUPATIONAL DISTRIBUTION OF APPLICANTS FOR EMPLOYMENT

Age Group	Teachers	Firemen and Ambulance Drivers	Clerical and Social Workers	Other	Total	
Men						
11–15	—	—	—	3	3	
16–20	3	4	10	5	22	
21–25	52	20	15	19	106	
26–30	64	20	40	25	149	
31–35	36	10	42	26	114	
36–40	24	7	16	16	63	
41–45	12	3	11	22	48	
46–50	10	6	5	23	44	
51–55	3	2	11	11	27	
56–60	3	1	5	8	17	
61–65	1	—	—	3	4	
66–70	2	—	—	1	3	
Total	210	73	155	162	600	
Women						Total men and women
11–15	—	—	—	—	—	3
16–20	9	—	16	1	26	48
21–25	86	1	33	5	125	231
26–30	42	1	28	2	73	222
31–35	22	—	36	5	63	177
36–40	17	1	14	3	35	98
41–45	8	1	17	6	32	80
46–50	10	—	13	2	25	69
51–55	7	—	3	4	14	41
56–60	1	—	3	—	4	21
61–65	3	—	—	—	3	7
66–70	—	—	—	—	—	3
Total	205	4	163	28	400	
Total men and women	415	77	318	190	1,000	1,000

The sex distribution was nearly equal in the two groups headed " teachers " and " clerical and social workers " (which among the males included mainly professional and administrative staff and among the females nurses, social workers, and clerical staff). There was a marked excess of men in the " firemen and ambulance drivers " group, the four women all being ambulance drivers. There was also an excess of men in the "other " group.

The age distribution shows that the women were slightly younger than the men, and this was very marked among the teachers, where half the women were under 25 years but only a quarter of the men were so aged. Taking both sexes together about a quarter of the people examined were over 40 years of age.

Applying the Pulheems classification it was found that 278 men (46·3%) and 177 (44·2%) women, a total of 455 (45·5%) people, had a normal or average profile of Pulheems (22211122). Table 2 shows the numbers with lower degrees in all the categories except EE (visual acuity). Excluding defective hearing and defective vision 156 (26%) of the men and 100 (25%) of the women showed one defect or more. (These figures are less than the totals of the figures in Table 2 as some persons showed multiple defects.) One hundred and nine (18%) of the men and 61 (15%) of the women were classified below P2, the majority being P7 or P8. P reflects more than physique alone; it is the " master quality " and can be affected by the other qualities. Thus a man with normal hearing but with chronic discharging otitis media would be classified P8H1, and from a civilian point of view he would be fit for most types of employment.

TABLE 2
INCIDENCE OF BELOW-AVERAGE QUALITIES

Quality	Degree	Men	Women	Quality	Degree	Men	Women
P	3	8	9	H	2	4	–
	6	11	8		3	9	3
	7	24	16		7	1	–
	8	66	28		8	1	–
U	3	3	3	M	3	1	–
	7	–	–				
	8	–	–	S	3	11	10
					7	2	3
L	3	27	34		8	9	7
	7	8	1				
	8	5	3				

After P the next most frequently defective quality was L. This showed an interesting sex difference, with 40 (6·5%) ranked as defective in men and 38 (9·5%) in women. The majority of these were L3 on account of minor foot defects, flat feet and varicose veins in men and hallux valgus in women. Quality H also showed an interesting sex difference, with 2·5% of the men but only 0·75% of the women having a defect graded as H3 or lower, measured as indicated above. Only two men were really hard of hearing. No tests were carried out for M (intelligence) but one known mental defective was examined. The assessment of quality S (emotional stability) depends mainly on the history, S3 signifying a definite history of a nervous breakdown or other mental trouble from which the person has recovered whilst S7 or 8 shows that the person is either very liable to recurrence or shows signs of existing instability. Twenty-two (3·7%) of the men and 20 (5%) of the women gave a history of psychological disorder and in both sexes about half the applicants had symptoms or signs of instability at the time of examination, the most usual symptoms being insomnia, fatigue, and anorexia.

The purpose of the Pulheems system is to classify both persons and jobs so that by matching the profiles of the two it is possible for any person (not

necessarily a doctor) to see the range of jobs for which the applicant is fit. Therefore, in the case of the 45% of applicants who had a normal Pulheems profile no useful purpose would have been served by adding their Pulheems profile to a straightforward statement that they were fit for employment. Thus, if the Pulheems system is to be of value it must be amongst the handicapped and the disabled that its advantages should lie. It is in this group that the foreman, supervisor, or headmaster needs precise guidance as to an employee's capabilities.

The fact that unfitness for military service, *e.g.*, P8 or S8, is insufficient guide for civilian employment is revealed by this survey. Although 12·5% of men applicants and 9% of the women applicants had P8 or S8 categories which would render them unfit for military service, only 4·8% of the men and 0·75% of the women were considered unfit for the civilian posts for which they were examined. Consideration of the main causes for classifying people as P8 in this survey shows the need for many subdivisions of P8 if the Pulheems system is to be of use in civilian practice. Pulmonary tuberculosis, peptic ulcer, and chronic suppurative otitis media were the three most numerous causes of a P8 rating in men. In civilian life pulmonary tuberculosis is only a bar to employment if the clinical condition of the patient is such that the disease would be aggravated by his work and if the patient might be a source of infection to the public or to other employees. The disease need not be entirely quiescent, for some chest physicians now allow their patients to resume work while still under drug therapy. If these patients are to be categorized many different factors must be considered, not least the details of the proposed employment and its location. Furthermore, an employer would be more likely to allow an established employee to resume work, perhaps under sheltered conditions, than to take on a new employee in the same clinical state. A single category of P8 does not allow for these important factors. For tuberculosis alone it would be necessary to have separate categories which showed the amount of physical work the person could undertake, the possibility of infection, and whether an indoor or outdoor environment was advised. In addition each type of employment would have to be correspondingly graded.

Most patients with peptic ulcers are employable and a grading of P8 is, from a civilian point of view, too low. The same applies to chronic suppurative otitis media, a disease that makes the sufferer unfit for military service. This condition is of little importance in civilian employment unless it is associated with deafness or occurs in food handlers or in people who need a particularly high standard of physical fitness, such as firemen.

Civilian employers under the Disabled Persons Act (1944) must employ at least 3% of registered disabled persons. Most concerns probably employ more than this quota. Judging by the figures in this survey at least 10% of the men and 6% of the women examined could have registered as disabled persons. Further, it by no means follows that the most disabled person is rejected, as for certain posts relatively minor defects are a bar to employment, such, for example, as defective eyesight in a fireman or ambulance driver.

Anomalies and Modifications of the Pulheems System

A system which attempts to overcome these defects of the Pulheems system has been elaborated by Hanman (1951) and according to Forssman (1955) a modification of Hanman's system has been tried out in Sweden with good results. The complexity of Hanman's system is indicated by the fact that he lists about 80 factors to be assessed, all of which may have a number of degrees. His system does not include any psychological factors.

In view of its apparent drawbacks it is interesting to consider the history of the development of the Pulheems system in the Army (Crew, 1953). At the start of the war four grades only were in use:—

Grade A = fit for general service, home and abroad
Grade B = fit for garrison and base service, home and abroad
Grade C = fit for home service only
Grade D = unfit for military service

These grades took little account of the multiplicity of employments available in the Army and thus tended to exclude people with defects who would nevertheless be fit for the more sheltered jobs in the Army. The civilian medical boards classified all the men they examined in Grade I, II, III, or IV. Grade I was normal, Grade II indicated minor defects, Grade III marked disabilities or evidence of past disease, and Grade IV unfit for any form of military service. As the disabilities were not specified the Army found considerable difficulty in allocating personnel appropriately.

In 1940 a system of medical grading in terms of military employment was introduced. The categories were designated A1, A2, B1, B2, B3, B4, B5, C, D, and E. A1 meant that the individual could see to shoot or drive, could endure severe strain, had no defects of locomotion, and only minor, remediable disabilities. He was fit to serve anywhere in the world. A2 was similar to A1 except that slight defects of locomotion were present. Men in the

B grades could only be employed on lines of communication, base or garrison duties, but could serve in the tropics, while men in the C grades were fit for home service only, had marked physical disabilities or evidence of past disease, and were considered unfit for considerable exertion. Grade D men were temporarily unfit and those in Grade E permanently unfit. Crew (1953) remarks :

> " Very soon after adoption it became apparent that large numbers of men were being placed in categories lower than those appropriate to their physical condition. The root of the matter was found to lie in the failure of medical officers when assessing physical capacity to distinguish clearly between the mere existence of a physical defect and the presence or absence of any functional disability arising directly as the result of that defect."

This is indeed the basic difficulty in all systems of medical classification, however complex they may be, for the amount of disability a defect causes depends as much on the personality and psychological environment as on the defect. Flat feet may not interfere with dancing, although they may be incapacitating when marching. A disability may be negligible as long as a job is congenial, but it may become unbearable when work palls. No satisfactory method of assessing these imponderable but essential qualities has been found. However, the Army continued to amend its system and having started with but four medical gradings had by 1943 introduced no fewer than 72 categories and subdivisions. The Pulheems system, originally adopted by the Canadian Army, was adopted by the British armed services in 1948. However, the difficulty of grading the individual soldier still remained. Crew (1953) writes:

> " In determining a man's category a medical officer specialist or medical board had to decide not as to a man's physical fitness to perform the job in which he was then engaged, but rather as to his capacity to perform all the numerous jobs which a man of his category might from time to time be called upon to undertake."

This led to wastage of manpower and was not overcome by the introduction of the Pulheems system. Indeed Crew reports:

> " During preliminary trials it was found that 13% of personnel that would have been classified A1 and therefore fit for service in front line units under the old category system were relegated to less active duties largely on account of a low degree of assessment in respect of M and S. Its greatest value was among personnel in the lower categories as it provided a finer screen."

Crew's finding is at variance with the experience of this survey, but the difference is due to the fact that the Services are not interested in finely screening major defects, all of which make an individual unfit for service, whereas these major defects are the very defects which need the finest screening in civilian practice. Lewis (1952) also mentioned some difficulties in the application of the Pulheems system.

> " The Pulheems system is not ideal. It depends a great deal upon subjective tests, which is a serious difficulty; also the provision of standards for comparisons presents a problem."

The R.A.F. also introduced the Pulheems system, but found that it did not provide a sufficiently fine screen for air-crew. Additional " employment standards " were therefore introduced which summarized the Pulheems profile and provided information to show the employability of an airman in respect of flying (Air or A) and ground duties (Ground or G). Under this system a fit pilot is graded A1G1 and normal ground staff are A4G1, meaning " fit to fly as a passenger and fit for all ground duties anywhere in the world ".

In addition to the difficulties and anomalies in the use of the Pulheems system experienced by the Services, other and wider problems are raised by its application in civilian life. First, in civilian practice there is a far greater range of ages, skills, and occupations than in the Services. Secondly, as has already been discussed, men in category P8 (unfit for military service) may be employable outside the Services. It is unthinkable that an individual who was found unfit for military service should *ipso facto* be denied employment in civilian life. Thus the lowest categories would need considerable breakdown and elaboration. Thirdly, the majority of employees apply for a specific occupation. For instance, a teacher applies to be a teacher and is not interested to know that he could also be a fireman, clerk, or sewer flusher; nor is the employer interested in this additional information.

Other objections to the widespread use of Pulheems may be made on ethical grounds. It is necessary to keep in mind the purposes and limitations of pre-employment medical examinations. The objects of the examination have been stated by Stevenson (1950) as (1) to protect a prospective employee from work which would endanger his health, and (2) to advise the employer as to the limitations of an applicant for employment. Newquist (1955), discussing this problem, also mentions: (3) to discover any correctable or controllable defects; (4) to provide a health base line for future comparative study; (5) to detect any communicable disease. And to these may be added (6) to protect the public and other employees from danger arising as a result of a disability in a fellow employee.

With the exception of (2) above, none of these purposes would be helped by the introduction of a system of categories. A clear statement by an industrial medical officer who is familiar with the requirements of the occupation regarding a man's fitness for that occupation is of greater value than a numerical summary of the applicant's physical and mental qualities. Every prospective employee should be considered individually for his work and no decision should be prejudiced because a military grading has previously been applied to him.

During the course of this investigation an unexpected value of the Pulheems system (or a modification of it) came to light. It was found useful as a ready-made numerical coding for statistical purposes. Figures covering each system of the body can be rapidly produced and compared. This part of the paper considers the incidence of the defects discovered during the investigation, relates this to other published data, and discusses the value of pre-employment medical examinations in the study of the general incidence of defects and disease in the population.

Results

The incidence of the main defects discovered in the population shown in Table 1 is shown in Table 3. But before discussing the incidence of these defects it is necessary to consider the limitations of the figures presented.

These figures cannot by themselves be taken as precise measures of the figures in the general population, for there are many biases. The prospective employee first selects himself for the job; in this survey only 12% of the firemen and ambulance drivers had defective vision, whereas the incidence in the whole group was 37%. Some people who fear they may be rejected on medical grounds no doubt avoid applying for a post with a concern known to carry out medical examinations of its employees. Some people are less than frank in their medical histories when applying for a job while they might exaggerate their disabilities to a National Service Medical Board. Other people might be too disabled to seek work; the low incidence of mental defects in this group of applicants may be due to this. Judging from the figures presented here there may also be a tendency for disabled women to stay at home, in contrast to the man who must seek some work. All these factors and others, such as the varying standards of medical examination between different investigators make the results of this investigation inapplicable to the population as a whole. Nevertheless, within these limitations some interesting points emerge.

TABLE 3

INCIDENCE OF DEFECTS

Disability or Defect	Men	Women
Limbs	47 (8%)	44 (11%)
Arthritis, deformities, etc.	15	7
Flat feet	10	4
Varicose veins	10	6
Poliomyelitis	3	1
Hallux valgus	2	21
Other	7	5
Pulmonary System	35 (6%)	14 (3·5%)
Pulmonary tuberculosis	19	6
Chronic bronchitis-emphysema	7	–
Asthma	7	6
Other	2	2
Psychological Disorders	24 (4%)	22 (5·5%)
Anxiety states, etc.	12	16
Schizoid type reaction	8	2
Affective reaction	2	2
Epilepsy	2	1
Other	–	1
Cardiovascular Disorders	15 (2·5%)	17 (4·25%)
Rheumatic valvular disorder	5	4
Hypertension	8	12
Congenital lesion	2	1
Gastro-intestinal Disorders	26 (4·5%)	5 (1·25%)
Peptic ulcer, gastrectomy	14	1
Dyspepsia	3	2
Hernia	8	1
Other	1	1
Ear, Nose, and Throat	18 (3%)	5 (1·25%)
Chronic suppurative otitis media	13	3
Otosclerosis	1	1
Other	4	1
Skin	8 (0·5%)	2 (0·5%)
Eczema	3	1
Psoriasis	2	1
Other	3	–
Urogenital System	3 (0·5%)	5 (1·25%)
Other	3 (0·5%)	10 (2·25%)
Diabetes	2	2
Gross obesity	–	6
Mastectomy	–	2
Retinitis pigmentosa	1	–

Foot Defects.—Defects of locomotion, particularly hallux valgus, showed a striking sex difference. Twenty-one (5·25%) of the women applicants had hallux valgus compared with only two (0·3%) of the men applicants. Flat foot was found in 10 (1·7%) of the men applicants and in four (1%) of the women; varicose veins were noted also in 10 (1·7%) of the men and in six (1·5%) of the women. Hewitt, Stewart, and Webb (1953) found the incidence of hallux valgus among male recruits examined for National Service to be 2·8%. These authors also found that there was an increased incidence in the lower social classes and that the incidence increased from 1·39% in men aged 17-19 years to 4·69% in those aged 40-44 years. When the rather small figures of the present survey were broken down into age groups it was found (Table 4) that the incidence in the women increased considerably with age; whether

this finding is due only to age or to some past fashion in ladies' footwear is not known. When their previous occupations were considered it was found that no less than one-third of the female applicants with hallux valgus had always been in sedentary work. No apparent social class difference was found.

TABLE 4
INCIDENCE OF HALLUX VALGUS BY AGE (FEMALE APPLICANTS)

Age (yr.)	No. of Applicants	No. with Hallux Valgus
Under 21	26	—
21–30	198	5
31–40	98	5
41–50	57	4
51–60	18	6
61–70	3	1
Total ..	400	21

Pulmonary Tuberculosis.—A history of pulmonary tuberculosis was given by 19 (3·1%) of the men applicants and by six (1·5%) of the women. These figures show the usual male preponderance and are within the limits of the figures found in mass radiological and other surveys. It is usually considered that 2-5% of adults have latent active lesions or recent (within five years) histories thereof. The rejection rate found among National Service recruits varied between 0·8% and 3·6% (Lee, 1955; Stewart, Webb, and Hewitt, 1955).

Psychoses, Neuroses, and Epilepsy.—A history of disabling neurosis was obtained from 12 (2%) of the males and from 16 (4%) of the females, showing the usual sex difference. The figures are almost certainly lower than the incidence in the population as a whole. Some cases were probably missed as there are no physical signs to mark a person recovered from a neurosis and the diagnosis is largely dependent on the history. The incidence of psychoses was 10 (1·7%) in the males and four (1%) in the females, again a low figure. The three cases of epilepsy found among these 1,000 applicants compares with the figure of 3 to 5 per 1,000 usually given as the incidence among the general population.

Cardiovascular Disease and Hypertension.—Hypertension (taken as a diastolic reading of over 100 mm. Hg after resting if necessary) occurred in eight (1·3%) of the males and 12 (3%) of the females. It is difficult to differentiate between hypertensive disease and high blood pressure. Both Fishberg (1954) and Pickering (1955) have found that up to the age of puberty the blood pressure in the two sexes is approximately equal and then from adolescence to about the age of 40 the blood pressure of men is higher than that of women. This difference gradually becomes less marked and is reversed after the age of 40. Neither of the above authors believes that the menopause itself plays any part in the pathogenesis of hypertensive disease which as a cause of death is slightly more common in men than in women. The females with hypertension in the present survey (of whom 11 were over the age of 40 years) might well include some within the upper range of normality.

The National Service rejection rate for hypertension (Stewart and others, 1955) was 0·5% but a marked age gradient was noted and the higher incidence in the older population considered here was to be expected.

Peptic Ulcers.—There was a large excess of males who gave a history of peptic ulcer, the figures being 14 (2·3%) in the males and one (0·25%) in the females. In service recruits Stewart and others (1955) found 1·18% of men aged 17 to 44 years had peptic ulcers. There was a marked age gradient and the figures found in the present survey agree generally with Stewart's findings. Doll and Avery Jones (1951) calculated the incidence of peptic ulceration in London to be 5·8% in men and 1·9 in women.

Other Conditions.—There was a marked male excess of chronic suppurative otitis media and chronic bronchitis and emphysema were only found in men.

Visual Acuity.—Visual acuity was measured using Snellen's test type. Any person failing to read 6/6 in each eye separately was considered to be defective. Three hundred and seventy-six (37·6%) of all the applicants were found to have a defect of vision, a finding very similar to that of Sorsby, Benjamin, and Yudkin (1955) who found some visual defect in 37% of adults between the ages of 21 and 40. In this survey the incidence in men was 216 (36%) of all men and 207 (39%) if firemen and ambulance drivers are excluded. This difference illustrates the difficulties of making general deductions from figures obtained from pre-employment examinations, for both firemen and ambulance drivers are interviewed before their medical examination and only exceptionally would a person wearing spectacles be referred for examination. The incidence of defects in the women applicants was 160 (40%), virtually the same as the 39% found in the men, excluding the firemen and ambulance drivers. Breaking the figures down into occupational groups there is little difference to be found, except that the less skilled groups (" other ") showed a lower incidence of

defect (32%) than the remaining groups (40-42%); this finding is the reverse of that of Stewart and others (1955). As already mentioned the firemen and ambulance drivers showed the lowest figure of all, there being only nine cases amongst 77 applicants (12%).

Table 5 shows the numbers and percentages in each age group with visual defects, men and women together. There is a considerable increase in defects after the age of 50. Sorsby and others (1955) (*op. cit.*) only investigated men up to the age of 40 years, but they found a steady increase in defects with age as also did Stewart and others (*op. cit.*).

TABLE 5

AGE INCIDENCE OF VISUAL DEFECTS (MEN AND WOMEN)

Age (yr.)	No. with Defects	Age (yr.)	No. with Defects
Under 21	9 (18%)	41–45	31 (39%)
21–25	77 (33%)	46–50	26 (37%)
26–30	69 (31%)	51–55	34 (66%)
31–35	69 (39%)	Over 56	22 (70%)
36–40	39 (40%)		
Total (men and women)			376

Out of the 376 cases with defective vision, 282 (75%) had both eyes defective and in 147 (52%) of these the defect was equal in each eye; in 82 (29%) the right eye was more affected than the left and in 53 (19%) the left more than the right. In the 94 (25%) who only had one eye defective, 53 (56%) had the left eye affected and 41 (44%) the right.

Colour Vision.—Colour vision was tested by means of Ishihara (1950) colour charts.* Defective colour vision was found in 39 (6·5%) of the men and in five (1·25%) of the women. No case of absolute colour blindness was seen. The male incidence was in agreement with previously published findings; for instance, Betenson (1955) gives a figure of 4% in schoolboys, Sorsby and others (1955) 5·8%, and Duke-Elder (1938) quotes figures between 4% and 8% for males but only 0·4% for females.

Urine Tests.—The urine was tested for albumin by the boiling test, the result being recorded as " trace " meaning the merest suspicion of a cloud, " one plus " signifying a definite cloud which is not entirely opaque, " two plus " a definite opaque cloud, and " three plus " a dense, almost solid cloud. Each specimen was also tested for glycosuria using Benedict's reagent. The results of the urine tests were noted in only 760 cases (459 males and 301 females) as these were not recorded until after the survey had been under way for two months. Albumin was present in only four specimens of the 459 males. Three of these men were under 35 years old and one of them was suffering from subacute nephritis. Two of the specimens from the 301 females showed albumin, in one case due to pyelitis and cystitis.

The figures given for the incidence of albuminuria in other groups vary considerably. Lyall (1941) found a figure of 0·55% among adult males examined for fitness for the Services, but quotes Diehl and McKinlay as giving an incidence of 5% in a group of university students. Recently Smiley (1955) found an incidence of 52% among a group of 87 accident-prone men and 7% in his controls. Some of this wide divergence may be due to differing definitions of " albuminuria "; it may be that some authors have ignored a " trace " and consider the test only positive at an ill-defined " one-plus " level. The cases in this series showed " one plus " in five cases and " three plus " in one case.

Glycosuria was found in five specimens from the men and in six from the women, one of whom was a known diabetic; in two known male diabetics the urine was sugar-free. Blotner (1946) found glycosuria in 2% of 69,088 male " selectees " aged 18 to 37 years. (The term " selectee " refers to those people examined for military service who have previously been examined by a local board; this board eliminates any person with gross disqualifying defects but the board did not screen out diabetics.) In Blotner's series 42% of those with glycosuria were considered to be diabetic. Previously he (Blotner and Hyde, 1943) had found an incidence of 0·8% among 45,650 candidates. Spellberg and Leff (1945) found glycosuria in 1·1% of 32,003 selectees. The average incidence would therefore seem to be about 1% which is in agreement with the present findings.

Modification of the Pulheems Profile for Record Purposes

In the light of the experience of this survey the following procedure is now adopted. In addition to recording clinical information on the medical examination form (which is difficult to analyse), the following facts are separately recorded for each examination: name, sex, year of birth, proposed occupation, the height, weight, presence and approximate quantity of albumin and sugar in the urine, systolic and diastolic blood pressure readings, whether a registered disabled person, colour vision, and the P, U, L, H, E, E and S qualities adapted from the Pulheems system. The EE degrees are recorded as 1 to 8 as in the Pulheems system, but the other qualities (with the exception of H) are only

* Tests for Colour Blindness. H. K. Lewis, London. 9th ed.

given a degree of 1, 2, or 3. In the case of P, U and L, 1 is normal, 2 means a disability of minor or even no significance, and 3 signifies a disability of importance from the medical point of view. This method of making a medical rather than purely functional assessment renders the findings more readily comparable between different occupations and between different medical examiners. The S quality is classified as S1 if there is no significant history of mental trouble, S2 if the applicant is now stable but gives a history of significant mental trouble, and S3 if the applicant is considered unstable at the time of the examination or if there is a history of mental breakdown within the previous two years. The quality H is like EE assessed functionally; H1 means that the applicant can hear a forced whisper at 10 feet, H2 that he hears the conversational voice at 10 feet, and H3 signifies deafness. Finally the actual defect is recorded. This system provides a simple and efficient method of collecting statistics of pre-employment medical examinations. As has already been shown such a system is of little or no value in selection and placement.

Summary

The Pulheems system of classification has been applied to 1,000 prospective employees. It was found that it provided too fine a screen for minor defects and too coarse a one for major defects. It was concluded that the Pulheems system could not usefully be applied to civilian employees and that it would be extremely difficult to modify the system so that it might be of use in widely differing industries and occupations. However, the system was found to be of value in collecting statistical information about the incidence of defects discovered at pre-employment medical examinations. Certain defects are discussed in detail including foot defects, pulmonary tuberculosis, psychoneurosis, hypertension peptic ulcers, defects of form and colour vision, and the incidence of albuminuria and glycosuria. A description is given of a modification of the Pulheems system for the purpose of statistical analysis of the results of routine medical examinations.

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DETERMINATION OF ATMOSPHERIC BENZENE CONCENTRATION BY DISPLACEMENT FOLLOWING ADSORPTION ON SILICA GEL

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In industries which employ solvents containing benzene, determination of the atmospheric content of this substance is an important and constant health problem.

Many of the methods of assessing benzene concentration described in the literature, including those of Jacobs (1949) and Elkins (1950), entail determination of the total aromatic content, and estimation of the atmospheric benzene concentration according to these methods frequently requires more or less time-consuming laboratory work. Some methods, such as absorption in alcohol or other solvents, necessitate effective chilling of certain parts of the apparatus during sampling in order to minimize loss of benzene. This may be difficult in field work.

Tiselius (1943) introduced a technique which may be used for various analytical purposes. The principle is that the fluid mixture to be analysed is adsorbed on, for instance, a column of silica gel, and then displaced by a substance which is more strongly adsorbed than any of the components of the mixture.

I have tested the displacement technique in analyses of atmospheric benzene concentration. Benzene vapour was adsorbed on silica gel. The eluent was absolute alcohol. The content of benzene in the percolate was determined. The advantages of the method are ease of sampling and concentration of the atmospheric benzene in a small quantity (1 to 5 ml.) of alcohol, which permits greater precision in the final spectrophotometric determination. Further, it is possible by means of absorption spectra to identify benzene in the ultra-violet region.

Preparation of Silica Gel

It is important that the gel should be free from impurities with absorption spectra in the ultra-violet region of 250 to 275 mμ. This is because the final determination of benzene is made according to the American Society for Testing Materials designation, D 1017-49T (ultra-violet absorption), except that absolute alcohol is used instead of iso-octane. The presence of such impurities may be detected by forcing absolute alcohol through a glass tube packed with activated silica gel and then measuring the absorptivity of the percolate in the region of 250 to 275 mμ of an ultra-violet spectrophotometer. Three brands of silica gel* tested in this way were absorbent in the region in question. By treating the silica gel in a Soxhlet apparatus with absolute alcohol, however, the absorbance could be reduced to a value which did not affect the measurements. The gel was then reactivated by drying for four hours *in vacuo* (water suction) at 135 to 140° C.

Adsorptive Capacity of the Silica Gel

The apparatus sketched in Fig. 1 was used to test the adsorptive capacity of the silica gel. When air is sucked through the apparatus, a weighed sample of benzene placed in tube A vapourizes and is adsorbed on the silica gel in tube C.

It was found that the adsorbed benzene tended to percolate through the gel with the air stream. Hence it was important to elucidate the velocity of this benzene movement. Two problems thereby arose and were investigated.

Problem 1.—Does the speed of benzene percolation alter when the air flow and the diameter of the adsorption tube are constant but the quantity of gel is varied, and is there a relationship between the amount of gel and the maximum time during which air can be sucked through the adsorption tube without loss of benzene ?

Problem 2.—How does variation of the air flow through the silica gel affect the velocity of benzene percolation when the diameter of the tube and the quantity of gel are constant ?

An air flow of 0·188 litres per minute was used in all the investigations of problem 1. In the first series of experiments the quantity of gel was 1·11 g. and the length

*Silica gels used were obtained from the Davidson Chemical Corporation, Baltimore 3, U.S.A. (mesh size 28-200 and " thru 200 "), and Silica Gel Ltd., Garrick Street, London, W.C.2 (mesh size 100-200).

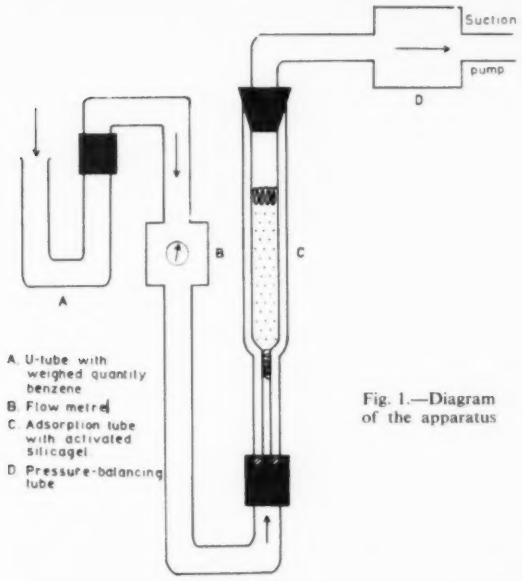

Fig. 1.—Diagram of the apparatus

of the gel column 50 mm. In the second series the corresponding figures were 2·22 g. and 100 mm. The inner diameter of the adsorption tube was 6·8 mm. in both series.

Air was sucked through the apparatus for a fixed time, after which the amount of benzene adsorbed on the gel was determined. If the yield was equal to the quantity placed in the U-tube, the period of suction was lengthened until loss of benzene was registered. The maximum time during which the benzene-containing air could be sucked through the gel without loss was 45 minutes in these experiments. The velocity of benzene through the silica gel was accordingly determined. The results are presented in Table 1.

Loss began after about 90 minutes in the 100 mm.

TABLE 1

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Time (min.)	Yield (%)	
	1·11 g. gel 50 mm.	2·22 g. gel 100 mm.
30	98	99
45	*97*	98
48	94	100
53	67	98
60	27	98
70	—	99
90	—	*96*
105	—	85
120	—	65
140	—	35

Inner diameter of adsorption tube 6·8 mm.
Velocity of air flow 0·188 l./min.

column of gel and after about 45 minutes in the 50 mm. column. Thus in both cases the benzene percolated through the gel at a rate of about 1·1 mm. per minute. Table 2 shows the velocity of benzene percolation when the inner diameter of the adsorption tube was varied.

TABLE 2

VELOCITY OF BENZENE PERCOLATION WITH ADSORPTION TUBES OF VARIED DIAMETER

Diameter of Adsorption Tube (mm.)	Silica Gel (g.)	Maximum* Time (min.)	Benzene Movement through Gel (mm./min.)	Maximum Time/ Gel Quantity
6·8	1·11	45	1·1	41
10·4	2·59	100	0·5	39
15·1	5·25	240	0·2	46

* Before benzene loss is registered.

When the air flow through the gel and the diameter of the adsorption tube were constant, therefore the percolation rate of benzene was also constant. Further, the quotient $\frac{\text{maximum time}}{\text{gel quantity}}$ was shown to be about 42. This constant is fully adequate to calculate a time margin for field sampling (*e.g.*, 10 g. gel gives a maximum time of $42 \times 10 = 420$ minutes).

The apparatus for the experiments to solve problem 2 was the same as for problem 1, except that the diameter of the adsorption tube was always 10·4 mm. and the length of the gel column 50 mm. The results are presented in Fig. 2.

As the flow of air increased from 0 to 0·2 litres per minute, the velocity of benzene percolation showed an almost linear increase (Fig. 2). With more rapid air flow, however, the curve of benzene movement rose more sharply.

Test Apparatus

The above principles for analysis of atmospheric benzene content were tested with the apparatus illustrated in Fig. 1.

The air to be analysed is sucked through the inlet pipe, the flow meter, and the adsorption tube, which is filled with activated silica gel. The pressure-balancing tube has an extra air intake, by means of which the pressure, and consequently also the air flow through the flow meter and the adsorption tube can be regulated.

The flow meter should be graduated to show about 0·15 to 0·25 litres per minute with an accuracy of $\pm$ 2%.

The adsorption tube consists of a wide and a narrower section. In my experiments the inner diameter of the upper section generally was 10·4 mm. (in some cases 6·8 or 15·1 mm.) and that of the lower section 1·5 mm.

Glass wool is placed at the junction of the sections to prevent the gel escaping into the capillary. The construction of the apparatus must permit easy changing of the adsorption tube. It may be connected to the pressure-balancing tube with, for instance, a pierced rubber stopper. The flow meter may be connected by means of a short tube of plastic or rubber material insoluble in benzene.

The pressure-balancing tube has two functions. It eliminates any pressure variations from the vacuum pump and by means of the extra air intake can alter the negative pressure.

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DETERMINATION OF ATMOSPHERIC BENZENE CONCENTRATION BY DISPLACEMENT FOLLOWING ADSORPTION ON SILICA GEL

BY

PER ÖVRUM

From the Department of Industrial Health, the National Institute of Public Health, Tomteboda, Sweden

(RECEIVED FOR PUBLICATION MARCH 13, 1956)

In industries which employ solvents containing benzene, determination of the atmospheric content of this substance is an important and constant health problem.

Many of the methods of assessing benzene concentration described in the literature, including those of Jacobs (1949) and Elkins (1950), entail determination of the total aromatic content, and estimation of the atmospheric benzene concentration according to these methods frequently requires more or less time-consuming laboratory work. Some methods, such as absorption in alcohol or other solvents, necessitate effective chilling of certain parts of the apparatus during sampling in order to minimize loss of benzene. This may be difficult in field work.

Tiselius (1943) introduced a technique which may be used for various analytical purposes. The principle is that the fluid mixture to be analysed is adsorbed on, for instance, a column of silica gel, and then displaced by a substance which is more strongly adsorbed than any of the components of the mixture.

I have tested the displacement technique in analyses of atmospheric benzene concentration. Benzene vapour was adsorbed on silica gel. The eluent was absolute alcohol. The content of benzene in the percolate was determined. The advantages of the method are ease of sampling and concentration of the atmospheric benzene in a small quantity (1 to 5 ml.) of alcohol, which permits greater precision in the final spectrophotometric determination. Further, it is possible by means of absorption spectra to identify benzene in the ultra-violet region.

Preparation of Silica Gel

It is important that the gel should be free from impurities with absorption spectra in the ultra-violet region of 250 to 275 mμ. This is because the final determination of benzene is made according to the American Society for Testing Materials designation, D 1017-49T (ultra-violet absorption), except that absolute alcohol is used instead of iso-octane. The presence of such impurities may be detected by forcing absolute alcohol through a glass tube packed with activated silica gel and then measuring the absorptivity of the percolate in the region of 250 to 275 mμ of an ultra-violet spectrophotometer. Three brands of silica gel* tested in this way were absorbent in the region in question. By treating the silica gel in a Soxhlet apparatus with absolute alcohol, however, the absorbance could be reduced to a value which did not affect the measurements. The gel was then reactivated by drying for four hours *in vacuo* (water suction) at 135 to 140° C.

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The apparatus sketched in Fig. 1 was used to test the adsorptive capacity of the silica gel. When air is sucked through the apparatus, a weighed sample of benzene placed in tube A vapourizes and is adsorbed on the silica gel in tube C.

It was found that the adsorbed benzene tended to percolate through the gel with the air stream. Hence it was important to elucidate the velocity of this benzene movement. Two problems thereby arose and were investigated.

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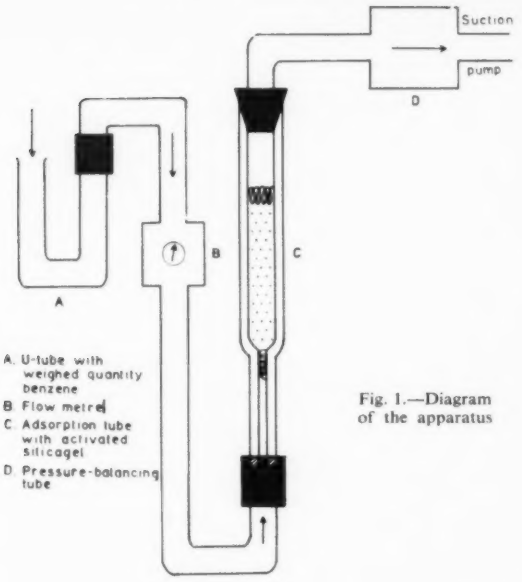

Fig. 1.—Diagram of the apparatus

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Air was sucked through the apparatus for a fixed time, after which the amount of benzene adsorbed on the gel was determined. If the yield was equal to the quantity placed in the U-tube, the period of suction was lengthened until loss of benzene was registered. The maximum time during which the benzene-containing air could be sucked through the gel without loss was 45 minutes in these experiments. The velocity of benzene through the silica gel was accordingly determined. The results are presented in Table 1.

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Inner diameter of adsorption tube 6·8 mm.
Velocity of air flow 0·188 l./min.

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The apparatus for the experiments to solve problem 2 was the same as for problem 1, except that the diameter of the adsorption tube was always 10·4 mm. and the length of the gel column 50 mm. The results are presented in Fig. 2.

As the flow of air increased from 0 to 0·2 litres per minute, the velocity of benzene percolation showed an almost linear increase (Fig. 2). With more rapid air flow, however, the curve of benzene movement rose more sharply.

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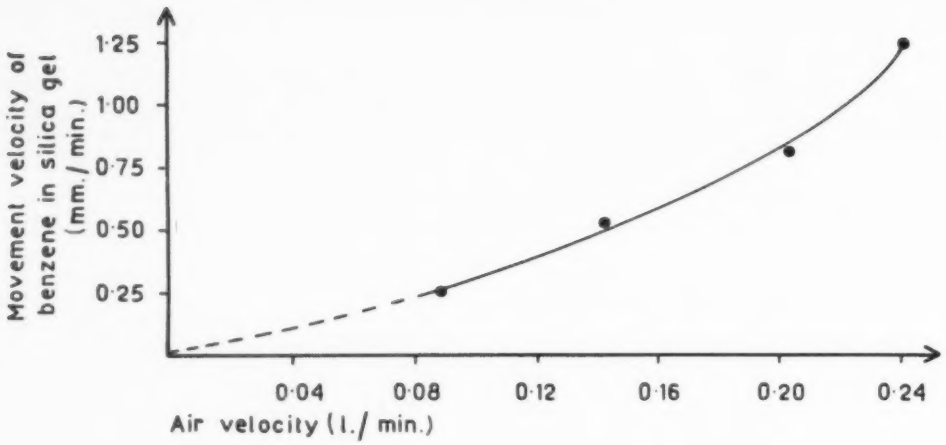
The pressure-balancing tube has two functions. It eliminates any pressure variations from the vacuum pump and by means of the extra air intake can alter the negative pressure.

Fig. 2—Results of experiments to solve problem 2.



The vacuum pump should be capable of a negative pressure of at least 100 mm. Hg in order to counteract the resistance in the adsorption tube. The pump must also be able to function continuously for several hours with this load.

Sampling

The adsorption tube is filled with about 5 g. of silica gel. The gel is well packed, preferably with a vibrator, until the volume does not diminish further. To hold the gel in position cotton wool is packed tightly above it with a glass rod. The adsorption tube is placed in the apparatus and suction of air is begun. From the flow meter the volume of air per unit of time can be calculated. When the desired volume has passed through the adsorption tube the tube is removed and placed in a stand. A volumetric flask with a capacity of 5 ml. and containing 1 ml. of absolute alcohol is placed under the tube. The tip of the capillary should be below the surface of the alcohol.

Into the upper part of the adsorption tube 5 to 10 ml. of absolute alcohol is then poured. The passage of the alcohol through the gel can be accelerated by weak positive pressure from an N_2 bomb. The displacement should take five to 10 minutes. The alcohol forces the adsorbed benzene through the column of gel and into the flask. To ensure that no benzene remains in the adsorption tube, 1 to 2 ml. of the eluting alcohol should also be forced down into the flask.

The volumetric flask is then filled to the 5-ml. mark with absolute alcohol. The benzene is identified and measured with a spectrophotometer. (The type used was a Beckman model DU.) As stated earlier, the benzene content was determined according to A.S.T.M. designation D 1017-49T (UV absorption). The spectroscopic solvent, however, was absolute alcohol instead of iso-octane. (Absolute alcohol which has been treated identically with the sample under analysis may also be used as the spectroscopic solvent.)

When sampling air in working premises a sufficient number of prepared adsorption tubes should be available. These should be sealed to prevent premature entry of air. The displacement and analytical procedures are performed later in the laboratory.

Testing the Method with Known Concentrations of Benzene

Series A.—Two connected carboys, each with a capacity of 63 litres and with fans for mixing gas, comprised the " gas chamber ". A mixture of benzene and n-heptane was pipetted into the carboys. The findings from these tests are presented in Table 3.

TABLE 3
RESULTS OF TESTS WITH KNOWN CONCENTRATIONS OF BENZENE

Test No.	Weighed Quantity of Benzene (mg./l.)	p.p.m.	Recovered Benzene (mg./l.)	p.p.m.	Yield (%)
1	0·0030	0·9	0·0028	0·9	94
2	0·0030	0·9	0·0027	0·8	90
3	0·0168	5·2	0·0162	5·0	96·3
4	0·2047	63·0	0·2013	62·0	98·3
5	0·2047	63·0	0·2020	62·2	98·7
6	0·2047	63·0	0·1985	61·1	97·0
7	0·2047	63·0	0·2008	61·8	98·1
8	1·093	336	1·060	326	97·0
9	1·093	336	1·066	328	97·5
10	1·093	336	1·076	331	98·4
11	1·093	336	1·082	333	99·0
12	1·093	336	1·068	329	97·7
13	1·093	336	1·068	329	97·7
14	0·9005	277	0·8951	276	99·4
15	0·9145	282	0·9108	280	99·6
16	1·280	394	1·310	403	102·3
17	1·280	394	1·300	400	101·6

The mean yield in series A, therefore, was 97·8±0·7% (range 90 to 102·3%).

Series B.—With the apparatus shown in Fig. 1, in which a weighed sample of benzene placed in the U-tube is vapourized in the air flow, 27 tests were made. The quantity of benzene ranged from 1·06 to 1·28 mg. The mean yield was 98·3±0·3% (range 96 to 100·8%).

Discussion

The method described here was shown to permit accurate quantitative study of atmospheric benzene. Concentrations as low as 0·003 mg. per litre (0·9 p.p.m.) were determined without difficulty and still lower benzene concentrations may readily be analysed if the quantity of gel is increased. An advantage of the method is that identification and quantitative estimation of atmospheric benzene can proceed simultaneously, even when the solvents employed have a very low benzene content.

The principles of the analytic procedure may also be applied in the determination of many other solvents in vapour form. Other adsorption media, eluents, and methods for the final analysis may then be necessary.

Summary

The displacement technique was used for determining atmospheric benzene concentrations. Air is sucked into a specially-shaped tube filled with activated silica gel. Adsorbed benzene is forced out of the gel by absolute alcohol and is collected in a volumetric flask. The concentration is then determined according to the American Society for Testing Metals designation D 1017-49T. The spectroscopic solvent, however, is absolute alcohol instead of iso-octane. The method was tested with benzene concentrations ranging from 0·003 to 1·28 mg. per litre of air. The mean yield was about 98%.

The writer is indebted to Dr. R. Vesterberg and Mr. S. G. Blohm, B.Sc., for valuable assistance in the development of this method.

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TWO CASES OF POISONING WITH DI-ISOPROPYLFLUOROPHOSPHONATE (D.F.P.)

BY

W. K. S. MOORE

From the Industrial Health Unit, Boots Pure Drug Co. Ltd., Nottingham

(RECEIVED FOR PUBLICATION OCTOBER 28, 1954)

Di-isopropylfluorophosphonate (D.F.P.) has the property of inhibiting the enzyme cholinesterase, and it has been recommended for use in the treatment of glaucoma, paralytic ileus, and myasthenia gravis. It is manufactured on a laboratory scale as this is sufficient to produce the quantities required for clinical use.

The circumstances in which two chemical workers were intoxicated with D.F.P. are reported together with some clinical details of their illnesses.

Method of Manufacture

Di-isopropylfluorophosphonate is prepared in three stages, the last of which involves the formation and isolation of D.F.P. by distillation from the reaction mixture. It is only the third stage which carries any risk of poisoning.

During this stage the area of the laboratory and its environs are made "out of bounds". The apparatus is erected in a fume cupboard where all manipulations are carried out. There are always three people present during the third stage, only one of whom requires to approach the fume cupboard, the other two standing by to give assistance in any emergency. All three workers wear rubber gloves, and, in addition, a respirator is put on before handling the apparatus in the fume cupboard. At the end of the process the apparatus is contaminated with traces of D.F.P. and the distillation flask itself contains a high boiling oily residue which may contain an appreciable amount of D.F.P. which has failed to distil over. For this reason, all the equipment used in the third stage must be treated with alkali in order to decompose any residual D.F.P. This is done by placing all the apparatus in a large vessel containing sodium carbonate solution for at least 48 hours before washing with water and drying.

History of Exposure

Di-isopropylfluorophosphonate was manufactured using these precautions during the week beginning Monday, November 9, 1953. When the preparation was completed on Friday, November 13, all the apparatus which had been used was placed in a large pan containing aqueous sodium carbonate solution and left during the weekend. The oily residue from the distillation sank to the bottom of the aqueous solution, and amounted to some 250 g.

On Monday, November 16, the sodium carbonate solution was syphoned out of the pan and replaced by water. This wash was repeated with another change of water. The apparatus was then removed to be washed and dried. No hand protection was used in this work. Certain pieces of apparatus were immersed in the oily layer at the bottom of the pan, and the workers' hands had to enter the oil in order to recover these components. Two men were engaged in this task, one of whom (G. H. S.) recovered most of the apparatus from the pan, while the other (T. H.) helped with washing and drying the glassware. They began work at 9.45 a.m. on November 16. At about 11 a.m. on the same morning G. H. S. noticed that the laboratory appeared to have become dimly lit, and for this reason he reported to the Surgery. T. H. did not notice any symptoms until he got home from work in the evening.

Case Histories

Case 1.—G. H. S. reported to the Surgery on November 16 at 11 a.m. He was 26 years of age, and had been employed by the firm since March, 1948. There was nothing relevant in his previous medical history. At his pre-placement medical examination his visual acuity was found to be R V 6/24 J 5, L V 6/6 J 1. No other abnormalities were noted.

He complained of dim vision, difficulty in focusing on near objects, and a tendency for his eyes to water. On examination his pupils were seen to be very small and they did not react to light or accommodation.

He was given a tepid alkaline bath and rested in the Surgery. At 2.30 p.m. he felt quite well, but still had

miosis. He was sent home by car. During the evening he noticed some pain behind the eyes. Between midday on November 16 and the morning of November 17 he had three bowel motions, which was unusually frequent.

After breakfast on November 17 he experienced nausea, his vision remained dim, and accommodation for near objects was lacking. There were no respiratory symptoms. When he was seen on November 17, the pupils were small and fixed. The finger-nose test was carried out inaccurately while his eyes were open, but improved in performance if he shut his eyes. The tendon jerks were brisk and equal. A blood sample was taken for cholinesterase determination.

He was given an intravenous injection of atropine, gr. 1/30, at midday. At 2.15 p.m. the pupils were dilated, and gave a small response to light. His mouth felt very dry, but by 3.30 p.m. moisture returned in his mouth. About this time he found that his stream of urine slowed and stopped during micturition, so that he had to make an effort to start again. By 6 p.m. this last symptom disappeared, and at the same time his vision suddenly became dim again.

On November 18 he had nausea after breakfast. His vision was dim, but he had infrequent periods of brightening during the day, and during these periods he could focus clearly on near objects. During the afternoon he felt very depressed for about three hours, and he was afraid that his vision would never become normal. At 9.45 p.m. his vision suddenly became brighter.

On November 19 his vision remained bright except for short periods when the dimming returned. On examination the pupils were less contracted, but the right pupil was a little larger than the left. The finger-nose test was quite normal.

On November 23 his vision was almost normal. The pupils were still unequal but reacted to light. He had the impression that his recovery had occurred in sudden steps rather than in a continuous and gradual way. Three months later his pupils remained unequal in size, but his visual acuity was the same as that recorded at his pre-placement examination.

CHOLINESTERASE ESTIMATIONS*

Date	Plasma (units)	R.B.C. (units)
17.11.53	34	101 (Warburg method)
7.12.53	97	110 (Warburg method)
28.12.53	121	114 (Warburg method)

*Normal values are about 100 units in both plasma and red cells.

Case 2.—T. H., aged 20 years, had been employed by the Company since 1949. No significant abnormalities were noted at his pre-employment examination, and there was no relevant medical history.

He helped G. H. S. to wash and clean apparatus on November 16, 1953, but so far as he could remember he did not touch the oily sediment in the vessel containing the apparatus. During the evening he noticed that the room he was in had become darker. On the morning of November 17 he had nausea and then he vomited. Contrary to custom he had three bowel motions between midday on November 16 and the morning of November 17. He experienced no respiratory symptoms, nor did he have pain in the eyes.

When he reported to the Surgery on November 17 the pupils were contracted and gave no reflex reaction to light or accommodation. He was given a tepid alkaline bath. A sample of blood was taken for cholinesterase estimation.

On November 19 his vision was almost normal, but he noticed that it was slow in adapting for brighter levels of illumination. His pupils were no longer contracted, and pupillary reflex reactions were normal.

CHOLINESTERASE ESTIMATIONS

Date	Plasma (units)	R.B.C. (units)
17.11.53	49	115 (Warburg method)
7.12.53	81	115 (Warburg method)
28.12.53	91	117 (Warburg method)

Discussion

Although there are obvious risks connected with the manufacture of D.F.P., no case of poisoning had occurred in this firm until the incident described here.

In this instance, the source of D.F.P. was an oily residue from the final distillation in the process, which lay at the bottom of a large pan under an aqueous layer of sodium carbonate solution. Various components of the apparatus which had been immersed in the oily residue were handled while being cleaned by the men who became affected.

It seems certain that the men's hands must have become contaminated with the D.F.P.-containing residue, and a certain amount must have been absorbed through the skin, thus causing a fall in the cholinesterase of the plasma. Di-isopropyl-fluorophosphonate, however, is a selective inhibitor of pseudo-cholinesterase (Hawkins and Mendel, 1947) which constitutes 99% of the cholinesterase content of human plasma (Mendel, Mundell, and Rudney, 1943) and it has been found that almost complete inhibition of the cholinesterase activity of human plasma can be produced with D.F.P. without causing serious distress (Bodansky, 1945; Mazur and Bodansky, 1946).

In the cases described here, two-thirds and a half of the plasma cholinesterase activity was lost, but these deficits are unlikely to be associated with systemic effects of acetylcholine poisoning. On the other hand, both men suffered alimentary symptoms as well as pupillary changes, and although the latter might be explained by assuming accidental introduction of D.F.P. to the eyes by hand or vapour, neither of these workers would be likely to put their hands to their mouths so producing direct contamination of the alimentary tract.

It is impossible to be certain of the exact sequence of events, and further discussion could only be based on assumption.

Once it was realized that the residue from the distillation in the last stage of the manufacturing process might contain dangerous quantities of D.F.P., a method of decontamination was devised, whereby further additions of sodium carbonate solution were stirred into the residue. The decomposition of D.F.P. is accompanied by effervescence; sodium carbonate solution is added so long as this continues.

Full protective clothing, including gloves, respirator, and gown, are worn during this procedure.

The cholinesterase estimations were carried out by Dr. E. N. Allott, Group Laboratory, Lewisham Hospital, London, S.E.11, to whom I am indebted.

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ARSINE POISONING

BY

D. BLAIR MACAULAY and D. AUSTEN STANLEY

From Bootle Hospital

(RECEIVED FOR PUBLICATION MARCH 26, 1956)

On June 20, 1952, at a tin smelting works in Bootle, six men were by mischance exposed to arsine gas of varying intensities. Two subsequently died. The following is an account of the nature of the accident, the clinical manifestations and the pathological findings, together with a review of the literature.

Nature of the Accident

Tin is manufactured on a very large scale in Bootle. It occurs naturally as pyrites, and arsenic is an invariable contaminant. The chemical composition of the ores varies considerably but arsenic is present in a concentration of up to 3%. The tin is liberated from its ores by heating with carbon. The arsenical impurities float to the surface of the molten tin and form a dross which has a high arsenical content. The dross is skimmed off and heated in another furnace in order to oxidize all the arsenic and in this form it is free of hazard. The tin is further purified by adding to it aluminium in the form of an aluminium-tin alloy. This causes the formation of aluminium arsenide, which has a higher melting point than that of tin and therefore floats to the surface as dross. It is a well recognized hazard of the tin smelting industry that this aluminium arsenide, when it comes into contact with water, generates arsine or arseniuretted hydrogen, which is highly toxic. Material which may contain aluminium arsenide is not, therefore, left lying about the factory.

On the day of the accident, a small amount of the dross from the aluminium-tin alloy melting was mixed with the roasted dross from the smelting furnace; the latter is known to be free from arsenide and the former is now known to contain it. This mixture was accidentally moistened. On this particular occasion, two men, J. E. and S. J., had been shovelling the dross mixture. A third man, A. B., was employed in bringing this dross by truck from another part of the factory. In error, he loaded also into the same truck some moist material which consisted of gutter cleanings put there by men who were repairing the roof. Thus, in the truck were mixed three substances: roasted arsenical dross from the smelting furnace, which is safe, dross from the alloy furnace, which had become contaminated with arsenic, and waste material containing moisture. This mixture generated arsine which caused the accident.

When the men were taken ill the Works Manager immediately suspected arsine poisoning, because a similar accident had occurred at this factory 21 years previously. He immediately sent the severely affected men into hospital, and instructed other workmen to attend hospital if they felt ill. He then caused the affected area to be cleared, and had bleaching powder spread over all suspected material to oxidize arsenical compounds.

Clinical Manifestations

Six employees developed symptoms. Of these Cases 1 and 2 were actually shovelling the wet dross and came into close and sustained contact with the fumes. They developed symptoms within an hour or two and were admitted immediately to Bootle Hospital where they both subsequently died. Cases 3, 4, and 5 attended Bootle Hospital Casualty Department the following day, Case 3 being admitted and the others transferred to Walton Hospital. At the same time, Case 6 was admitted to Waterloo Hospital.

Case 1.—J. E., aged 23 years, while engaged between 1.40 and 2 p.m. in shovelling the dross mixture felt light-headed, reported sick, and was sent to hospital. On arrival, at 4.30 p.m., he was complaining of numbness and coldness of the hands, nausea, headache, pain in the loins, and severe colicky abdominal pains. Shortly after admission he vomited and passed dark greenish-black urine. His temperature was 100·5° F. A diagnosis of arsine poisoning was made and he was given 100 mg. "dimercaprol" (B.A.L.) and this was repeated four-hourly for five further doses. An intravenous dextrose

saline was administered with additional calcium gluconate.

That evening the haemoglobin was 75% (11·1 g. %). By 10 a.m. next day the haemoglobin had fallen to 55% (8·1 g. %), R.B.C.s to 2·6 million, and the blood urea level was 88 mg. %. He was still vomiting but the pains in the loins and abdomen were less, probably as a result of the sedative effect of pethidine, 50 mg. The skin had become a dusky bronze colour and the conjunctivae were evenly suffused and red. He was anuric. An electrocardiogram showed normal complexes. Blood withdrawn from a vein and immediately centrifuged produced plasma the colour of a dark port wine. One pint (570 ml.) of matched blood and 1 pint (570 ml.) of dextrose saline were administered intravenously. At midday the blood urea level was 120 mg. %. By 11 p.m. the blood urea level had risen to 176 mg. %. In an attempt to improve renal circulation 2 ml. of heavy nupercaine was injected intrathecally to produce a high spinal anaesthesia. Two hours later he passed 8 oz. (235 ml.) of nearly black urine and seemed a little better. During the next 24 hours his condition steadily deteriorated. Fluid by mouth (Bull's régime) even in restricted quantities was poorly retained. One pint (570 ml.) of glucose saline was administered intravenously. A further 9 oz. (252 ml.) of dark urine was passed during the day and a blood-stained motion was evacuated. There were intervals of delirium. The spinal anaesthetic was repeated without any benefit and he died at 11 p.m., approximately 57 hours after exposure to the arsine.

At necropsy the whole of the skin was pigmented a reddish brown colour. The conjunctiva of both eyes was yellow. The tongue was stained green. Both kidneys were enlarged and congested. The right kidney weighed 7 oz. and the left kidney 7½ oz. The spleen was enlarged, weighing 10½ oz. The stomach contained a little mucus only and there were a few petechial haemorrhages in its mucous membrane. The lungs showed bilateral hypostatic pneumonia. The bladder contained about half an ounce of fluid with the appearance of blood. There were no haemorrhages in the bladder wall.

Estimates of arsenious oxide and arsine gave the following results.

TABLE I

ANALYSIS OF ARSENIOUS OXIDE AND ARSINE AT NECROPSY

Substance	Arsenious Oxide (p.p.m.)	Arsine (p.p.m.)
Blood	Trace	Trace
Contents of bladder ..	8	6·3
Liver	15	11·8
Spleen	10	7·9
Kidney	4	3·2
Brain	0·8	0·6

Case 2.—S. J., aged 33 years, was working side by side with J. E. and felt ill simultaneously. He was admitted to hospital at 4.30 p.m. At work he had complained of feeling sick with burning lips and excessive sweating within an hour of the onset of exposure. On admission he complained of numbness and coldness of the hands and feet, headache, severe pain in the loins, and abdominal colicky pains. Soon after admission he vomited dark brown fluid. He was ordered 100 mg. " dimercaprol " (B.A.L.) four-hourly, pethidine, 50 mg., for the pain, and a glucose saline with calcium gluconate added was given by intravenous drip. Five hours later the skin had become bronzed, the conjunctivae were evenly blood-stained, and a small amount of almost black urine was passed. The tongue was coated with brown fur, the pulse was 90 per minute with a poor volume, and he was sweating profusely with a normal temperature. The headache and backache were still distressing. Haemoglobin was 56% (8·3 g. %). Vomiting continued throughout the night and the temperature rose to 100° F. Next morning there was still total anuria but a loose, dark, reddish-brown stool was passed. Blood withdrawn from a vein and immediately centrifuged produced a dark serum similar to that of Case 1. The blood picture was: Hb 52% (7·7 g. %), R.B.C.s 2·56 m., blood urea level 88 mg. %.

Two pints (1,140 ml.) of matched blood were given but anuria persisted. At 11 p.m. high spinal anaesthesia was administered with no relief of the anuria or vomiting. The following morning the blood picture was, in spite of transfusion, Hb 50% (7·4 g. %), R.B.C.s 2·47 m., blood urea level 235 mg. %.

Before midday 10 oz. of dark urine was passed. Bull's régime was started but poorly tolerated. A further high spinal anaesthetic produced no urine. From this time the patient's condition gradually deteriorated. Haemolysis was still continuing, and on June 25 (five days after exposure) the blood picture was: Hb 38% (5·6 g. %), R.B.C.s 1·94 m., blood urea level 230 mg. %.

Small quantities of urine were passed daily. A further blood transfusion of 1 pint (570 ml.) was given with little benefit. Electrocardiograms on June 21 and again on June 25 were normal. The patient died on June 29 (ninth day of illness). Fig. 1 gives the results of the investigation of blood cytology and biochemistry throughout most of his illness.

Necropsy showed that death was due to pulmonary oedema. The kidneys were swollen and congested, and microscopically showed extensive tubular necrosis and they were blocked by haemoglobin casts. The skin colour had faded considerably and there was no jaundice. The intestines showed a greyish black discoloration. There was blood-stained urine in the bladder.

Case 3.—J. H., aged 32 years, was working near the first two patients, but was not actually shovelling the dross. On the day of exposure he felt nothing beyond a slight headache. He went home at the usual time, had a few drinks in the course of the evening, and went to bed feeling well. Between 1 and 2 a.m. (12 hours after exposure) he woke feeling sick and vomited. In the morning he noticed that his urine was red. He went to work and was sent to Bootle Hospital where he was admitted from the Casualty Department.

On admission he had no symptoms. The conjunctivae were slightly reddened. The urine was very scanty and

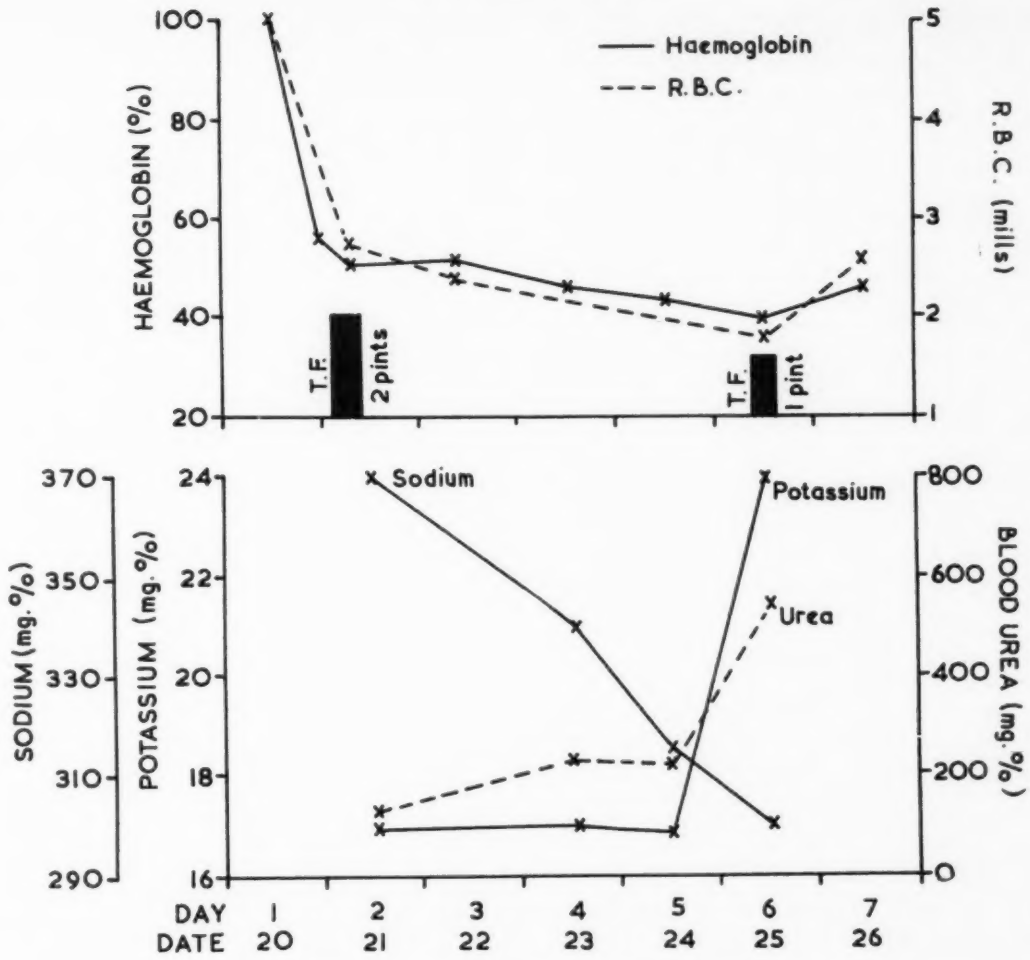

FIG. 1.—Results of cytological and biochemical investigations in Case 2.

reddish brown. The temperature was 101° F. Centrifuged plasma was slightly stained with haemoglobin. Haemoglobin was 100% (14·8 g. %). The following morning the haemoglobin reading was 90% (13·3 g. %) and R.B.C.s 4·9 m. The blood urea level was 35 mg. % rising to 44 mg. % the following day.

A high spinal anaesthetic was given at 11 p.m. on June 21. By the following morning he was passing urine freely and by June 24 the colour of the urine was nearly normal. Apart from a feeling of general weakness he kept well and was discharged on June 30 (tenth day of illness). The blood urea level was by then maintaining a steady level of 35 mg. %. He remained under observation as an out-patient for some months and made a complete recovery.

Cases 4, 5, and 6 were admitted to other hospitals and through the courtesy of Dr. Summers we have seen their case notes. They all exhibited haemoglobinaemia and some degree of anaemia, but all made a satisfactory recovery.

Discussion and Review

The nature of the exposure to arsine, while unusual, is not unique. Hamilton and Hardy (1949) state that the most frequent cause of industrial poisoning by arsine is in the cleaning out of tanks with a heavy acid (HCl or H_2SO_4), the acid acting on arsenic-bearing metals. Accidents in the tin industry, due to wetting of the dross, were described by Legge in 1924 who quotes six reports of a total of 30 cases with 12 deaths. Through the courtesy of Dr. Robert Coope we have had access to the records of two previously unreported cases in this

same Bootle smelting works who were admitted to Liverpool Royal Infirmary on November 16, 1931, five days after exposure under very similar circumstances. One patient was moribund and died within 24 hours. He was stated to be " bronzed, especially over the face, the nipples were black, and the conjunctivae were bloodshot. He had tenderness in both loins ". The urine report was " dark red, a few R.B.C.s, oxyhaemoglobin and methaemoglobin in large amounts ". The other patient had considerable haemolysis (R.B.C.s 3·5 m., Hb 35%), abdominal cramp, tenderness in the loins, and red urine, but this cleared rapidly and he was discharged in 10 days with a normal urea clearance test and a blood non-protein nitrogen level of 20 mg. %. A more recent outbreak in Indiana was fully reported by Spolyar and Harger (1950) and by Pinto, Petronella, Johns, and Arnold (1950). In this series 50 workmen (all negroes) were exposed to the fumes from storage drums of dross obtained during the manufacture of a lead-tin alloy. The drums had been exposed to rain, and arsine fumes thereby generated. Of the 50 men at risk, 13 developed toxic symptoms and four died. Locket, Grieve, and Phillips (1952) have described a recent fatal case of arsine poisoning in this country and have reviewed some of the literature. One of us has had the wartime experience of investigating suspected arsine poisoning in submarine personnel and observed that submarine commanders were well aware of the risk of arsine being generated during battery charging if the lead plates contained arsenic.

In comparing the above cases with those described in the recent literature some important facts emerge.

Mode of Onset.—The heavier the exposure to arsine gas, the sooner was the onset and the greater the gravity of the prognosis. Early symptoms in our cases were dizziness and nausea within two hours of exposure, followed by abdominal colic and pains in the loins. These loin pains were not observed in the Indiana series (Spolyar and Harger, 1950; Pinto and others, 1950), but were stressed by Jones (1907) in an earlier record.

Discoloration of urine appeared in four to 12 hours. In the milder cases it appeared later but was the first and only symptom of illness.

Within 12 hours the more seriously affected cases had developed conjunctival staining of a reddish colour probably due to haemoglobin and the skin had become duskily bronzed for a similar reason. The colour of the conjunctiva and skin produced by the presence of haemoglobin is quite unlike jaundice which is due to the presence of bilirubin. Glaister (1908) (quoting Maljean) wrote in 1908 that " the colour of these patients resembles jaundice only at first sight ". Most standard textbooks still erroneously describe this pigmentation as " jaundice ". None of our patients reached high levels of bilirubinaemia, and Pinto in his series states that " in only one patient (out of 13) was there any suggestion of jaundice. The bilirubinaemia was found to be 3 mg. on the fourth day after being exposed to arsine ".

Haemolysis was rapid and severe in all cases and was only temporarily checked by blood transfusions.

Dimercaprol (B.A.L.) was given to the three most seriously affected cases without any apparent benefit. This is in agreement with the findings of all workers and also with experimental work on animals (Kensler, Abels, and Rhoads, 1946). It was felt, however, that if patients recovered from the acute renal lesion, the use of B.A.L. might prevent later symptoms of arsine poisoning.

Course of the Disease.—The anuria which followed on the haemoglobinuria did not differ from the anuria of an incompatible transfusion or of blackwater fever. The danger of hyperpotassaemia has been stressed. Pinto regards the electrocardiographic evidence of this (exaggerated T waves) as one of the earliest and most sensitive signs for the diagnosis of arsine poisoning. None of our patients exhibited this electrocardiographic change and in none of them was the serum potassium level materially raised, except terminally. From the onset of the condition a very considerable amount of intracellular potassium must have been liberated and a further amount of potassium had been introduced into the circulation by blood transfusion. No appreciable potassium loss could have occurred by renal excretion. The fact that serum potassium levels remained normal for many days in spite of the above suggests that some regulating mechanism was operating until very shortly before death. With the danger of hyperpotassaemia in mind, transfusions were given sparingly—in the event probably too sparingly. The high spinal anaesthetic given in an attempt to improve renal circulation was a forlorn hope and met with no success. It was felt that the diuresis which followed it in Case 3 would have occurred in any case.

Summary

Arsine poisoning affecting six employees at a lead works is described.

The nature of the hazard is discussed.

Clinical and pathological findings are described and discussed.

Our thanks are due to Dr. G. B. Manning who carried out the necropsy on Case 1 (J. E.), to Dr. J. B. Firth

of the North Western Forensic Science Laboratory for the estimations of arsenious oxide and arsine, and to Professor Sheehan for his interest and advice.

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ASSOCIATION OF INDUSTRIAL MEDICAL OFFICERS: 21st ANNIVERSARY MEETING

The 21st Anniversary Meeting will be held in London from Monday, September 24, until Friday, September 28. All the scientific sessions (except the Mackenzie Industrial Health Lecture) will be held at The London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1.

The first day of the meeting will be devoted to registrations and to a reception at Canterbury Hall, Cartwright Gardens, W.C.1, when the London Group of the Association, the organizers of the Meeting, will be the hosts.

An exhibition illustrating the work of the Ministry of Supply Medical Service will be opened on the first day of the meeting between 2 and 6 p.m. in the Pillar Hall, Whitehall Gardens, S.W.1, and will be open each day of the meeting.

On Tuesday, September 25, at 10 a.m., the inaugural meeting will be opened by The Rt. Hon. Iain MacLeod, M.P., and will be followed by the Presidential Address by Dr. R. S. F. Schilling.

PROGRAMME OF SCIENTIFIC MEETINGS

Tuesday, September 25

11.15 a.m. " The Elderly Worker "

Chairman: Donald Stewart, M.D., F.R.C.P. (Ed.), Chief Medical Officer, Austin Motor Company, founder member of the Association.

Opening paper by Professor Sven Forssman, M.D., Medical Adviser to the Swedish Employers' Confederation, President of the Permanent International Committee on Industrial Medicine, Associate Professor of Occupational Health, Karolinska Institutet, Stockholm.

" The Health Problems of the Older Worker—A Study in Swedish Industry "

Discussion to be opened by A. Meiklejohn, M.D., M.R.C.P., Past President of the Association.

3.0 p.m. In the Great Hall, B.M.A. House, Tavistock Square, W.C.1.

The British Medical Association Mackenzie Industrial Health Lecture

Chairman: Alex H. Hall, O.B.E., M.D., President, British Medical Association.

Lecturer: R. S. F. Schilling, M.D., M.R.C.P., D.P.H., D.I.H., Reader, Nuffield Department of Occupational Health, University of Manchester; Editor, *British Journal of Industrial Medicine*.

" The Assessment of Health in Industry "

Wednesday, September 26

9.30 a.m. " Research in Occupational Health "

Chairman: M. W. Goldblatt, C.B.E., M.D., M.R.C.P., Ph.D., D.I.H., Director, Industrial Hygiene Laboratories, Imperial Chemical Industries Ltd., Past President and founder member of the Association

Speakers: The Earl of Verulam, M.A., F.I.I.A., Comp. I.E.E., J.P., Chairman, Enfield Rolling Mills Ltd.

Sir Harold Himsworth, K.C.B., M.D., F.R.C.P., F.R.S., Secretary, Medical Research Council.

Sir Alfred Roberts, C.B.E., M.A., J.P., Past President, Trades Union Congress.

11.30 a.m. A Discussion on " Research in Occupational Health " will be opened by J. N. Morris, M.A., M.R.C.P., D.P.H., J.P., Director, Social Medicine Research Unit, Medical Research Council.

Thursday, September 27

9.30 a.m. " The Impact on Medicine and Industry of the Use of Atomic Energy "

Chairman: W. Blood, O.B.E., M.R.C.S., L.R.C.P., D.I.H., Senior Medical Officer, J. Lyons & Co. Ltd., Past President of the Association.

Speaker: E. Katharine Williams, B.Sc., M.B., B.Ch., M.R.C.P., D.I.H., Research Group Medical Officer, Atomic Energy Research Establishment.

11.0 a.m. Lecture - Demonstration on "Weight Handling"

Chairman: A. J. Amor, C.B.E., M.D., M.Sc., D.I.H., Principal Medical Officer, Imperial Chemical Industries Ltd., Past President and founder member of the Association.

Speaker: Mr. Robert J. McD. Maxwell, F.F.Ph., M.S.R., Senior Physiotherapist, Ardeer Factory, I.C.I. Ltd., Stevenston, Ayrshire.

There will also be a demonstration by two weight-handling instructors.

3.0 p.m. The Association of Industrial Medical Officers, John C. Bridge Memorial Lecture

Chairman: S. A. Henry, M.A., M.D., F.R.C.P., F.R.C.S., D.P.H., D.T.M., formerly H.M. Medical Inspector of Factories.

Lecturer: Professor R. E. Lane, M.D., M.Sc., F.R.C.P., Nuffield Professor of Occupational Health in the University of Manchester; Physician, Salford Royal Hospital; Past President and founder member of the Association.

"The Place of Occupational Medicine in a Teaching Hospital"

7 for 7.30 p.m. Anniversary Dinner at The Royal College of Surgeons, Lincoln's Inn Fields, W.C.2.

Friday, September 28

10.0 a.m. "Mental Health Industry"

Chairman: L. G. Norman, M.D., B.S.c., M.R.C.P., D.P.H., Chief Medical Officer, London Transport Executive; Past President of the Association.

Speakers: R. F. Tredgold, M.D., D.P.M., Physician, Department of Psychological Medicine, University College Hospital.

A. Heron, M.Sc., Ph.D., Deputy Director, M.R.C. Group for Research on Occupational Aspects of Ageing, University of Liverpool.

Elliott Jaques, M.A., M.D., Ph.D., Social Science Consultant, Glacier Metal Co. Ltd.

11.30 a.m. Discussion on "Mental Health in Industry"

To be opened by J. J. O'Dwyer, C.B.E., B.A., M.B., B.Ch., D.P.H., Immediate Past President of the Association.

12.15 p.m. Closure of Meeting by the President of the Association of Industrial Medical Officers.

MISCELLANEA

The Prescription of Industrial Disease

RONALD E. LANE

During the last few years there has been a feeling in some quarters that the provisions of the National Insurance (Industrial Injuries) Act relating to diseases caused by occupation have been unnecessarily rigid. In May, 1953, the Minister of National Insurance set up a Committee under the chairmanship of Mr. F. W. Beney, Q.C., to " review the present provisions of the National Insurance (Industrial Injuries) Act under which benefit is paid for diseases and for personal injuries not caused by accident and to make recommendations ". In August last the Committee published its report*; unfortunately, this was not unanimous and the Trade Union members of the Committee furnished a minority report.

Under the Act the Minister is empowered to prescribe by regulation certain diseases acquired in certain occupations which qualify the sufferer for a higher rate of benefit than is provided under the National Insurance Acts. It had been suggested that prescription was restrictive and unfair and that the Act should treat diseases in the same way as accidents and provide cover for all diseases that could be shown to be due to occupation. The Committee agreed that if it were practicable such cover would be the proper one, but after hearing much evidence it decided that such a scheme was not workable. Whereas the proof that an accident occurred at work was comparatively easy, the attribution of many diseases to occupation was difficult and often impossible. Many of the questions that arose were unanswerable in the present state of medical knowledge.

> " A man working out of doors might claim that ordinary climatic conditions were a cause of his arthritis. A clerk might allege that the sedentary nature of his work over many years was responsible for his chronic indigestion or even his coronary thrombosis. A manager or someone else whose work involved mental stress might claim that this was the cause of his peptic ulcer or perhaps of his neurosis."

It was regarded as futile to expect individual doctors to answer questions that the medical profession as a whole could not answer. Inevitably different decisions might be given on cases presenting similar facts. Medical certificates would tend to fall into disrepute and a litigious atmosphere might develop, with protracted disputes which would have an adverse effect on health. A great number of claims would probably be rejected, with resulting disappointment and dissatisfaction. When it is remembered that bronchitis and rheumatism alone account for well over a million spells of sickness each year it will be realized how widespread this dissatisfaction might become.

For these reasons the Committee concluded that general cover was not practicable and turned to examine another suggestion, namely that of providing cover for those who work in certain unfavourable environments and develop a common disease which might be related to those working conditions, for instance sufferers from chronic bronchitis whose work exposed them to abrupt changes of temperature. Such a scheme, however, would give all patients on this type of work who suffered from chronic bronchitis an irrebuttable presumption that their disease was caused by their work. This would obviously be unjust to the fund and would in fact be opposed to the industrial injuries scheme which requires that the individual case is capable of proof. The Committee therefore rejected this suggestion and decided that the system of prescription should remain.

The Committee then considered the present working of the Act and reviewed the requirements for prescription. The conditions which must be satisfied before a disease can be prescribed are contained in the famous Section 55 of the Act. Subsection (2a) of this Section deals with the scientific information about the disease establishing its relation to occupation, while Subsection (2b) deals with the feasibility of proving causation in the individual case. The principle defined in Subsection 55 (2b) caused the Committee much difficulty. The Samuel test in the old Workmen's Compensation Act required this proof uncompromisingly; the present Act requires it, but less rigidly; as defined by the Dale Committee this condition is satisfied if proof is of the same standard as required in civil law cases, *e.g.*, " more likely than not ". For instance, this condition has been regarded as satisfied where an exceptionally high incidence of a disease occurs in a given occupation—such as cancer of the bladder in chemical workers. It has also been regarded as being satisfied in tuberculosis among health workers, though here the excess incidence is much less. The Committee points out, however, that in general " arithmetical tests " are unsatisfactory for this purpose since it can never be known whether the particular claimant under consideration is one of the " excess " or would have been found among the " normal incidence ".

The minority report seizes on this argument and points out that in both these instances it is rarely, if ever, possible to be certain whether any individual case is of occupational origin. Accepting the prescription of these two diseases as sound (as does the whole committee) the minority report goes on to urge that incidence rather

* Report of the Departmental Committee Appointed to Review the Diseases Provisions of the National Insurance (Industrial Injuries) Act.

than the attribution of individual cases must be the method which determines prescription in the future. The T.U.C. members press that a disease should be prescribed if its occupational origin can be presumed to be more probable than not: that " most cases in the field covered are occupational " and that individual attribution should be disregarded. It would seem here that the majority and minority are not far apart. The question would appear to be what measure of excess incidence (after adequate statistical determination) is to be regarded as adequate for prescription, and for assuming 55 (2b) to be satisfied. The majority report speaks of " an exceptionally high incidence ", the minority speaks of " most cases ". It would seem that this is a practical point which can be settled by the Minister in each submission for prescription.

This is, however, an over-simplification, for there is a fundamental difference between the two reports. The majority is prepared to accept a high incidence of a common disease when it occurs in a well defined occupational group as satisfying 55 (2b), but it flatly refuses to accept the view of the minority who would carry this principle much further and would seek to apply it without clear definition of the occupation and for common disease, for instance, chronic bronchitis in those exposed to dust. If this principle were pressed prescription would disappear and it would be open for any patient to prove if he could that his disease arose from his occupation, with the obvious difficulties associated with " general cover ". Nor would this be all, for the problem of aggravation would loom up and doctors would be asked to guess whether and to what extent certain conditions of work had aggravated a pre-existing constitutional disease.

One gets the impression from reading the report that if some way could have been discovered of dealing with chronic bronchitis and rheumatism the minority's demand for more general cover might have been dropped. The minority report says that failure to provide cover for these two diseases is a great weakness in the existing system. Recognizing the difficulties, however, it suggests as a start that special provision should be made for older workers who have spent the greater part of their working lives in a job carrying special risk of these diseases. It is pointed out that cover could be limited by the degree of disability and duration of exposure which could be determined by special medical boards. It is interesting to recall that this was until recently the scheme for dealing with byssinosis and that it worked satisfactorily for some 14 years. There was, however, this great difference, the occupation was clearly and precisely defined. The majority report rejects this as a feasible method of dealing with the general problem since at present there is no way for a doctor to differentiate occupational from non-occupational cases.

The Committee emphasizes that if extra benefit is to be given on uncertain evidence, the present industrial injuries scheme would break down. Such a practice would have the effect of transferring many cases from the National Insurance Scheme to the Industrial Injuries Scheme and the final outcome of this might well be a merging of the two schemes. Since these are both welfare payments it might well be asked why this separation should be retained. The needs of a man who breaks his leg differ in no way whether the accident occurs at home or at work. It is true that at present he pays a little more for extra cover but there would seem no insuperable difficulty in dropping this and merging the two schemes. If there is to be a demand to extend cover to disease which cannot be proved to be industrial such a change would appear to be the only solution.

If in fact the two schemes are to be kept separate some means must be found to identify those cases of common disease which result from occupational exposure. The Committee recognized that such cases existed but differed in their method of handling the problem. The majority infer that this is a very small group and that by attempting to pay them the larger benefit to which they would be entitled under the Industrial Injuries Scheme more harm than good would be done. The minority on the other hand would prefer the few to get their " rights " at the expense of considerable injustice to the Scheme.

The Committee evidently struggled hard to find some way of covering the group of cases which were at present missing benefit. For instance, the possibility of " open prescription " was considered. This is the name the Committee gave to prescription without presumption. At present the only disease in this category is dermatitis where entitlement to benefit has to be shown even though a skin lesion is present. The Committee decided that at present no other disease was known to which this type of prescription could be applied with advantage. Such a device would, in fact, produce the same situation they were at pains to avoid, namely, the settlement of claims not on fact but on the unverifiable opinion of individual doctors.

It is not surprising, therefore, that in this impasse both majority and minority call for more knowledge—for further research in this field—and the committee is unanimous in making recommendations as to how this should be done. It is not suggested that the Ministry of Pensions and National Insurance should set up its own research organization but that the Industrial Injuries Advisory Council should keep under review the list of prescribed diseases and assume the responsibility for initiating research into current problems of prescription. In order to assist it in its work the Committee recommended the formation of a small highly qualified specialist staff and suggest that those members of the Council " concerned with industrial diseases " should keep in close touch with this staff and " provide the necessary supervision ". The importance of field studies and statistical techniques is emphasized.

The report makes no mention of the very considerable practical difficulties there would be in carrying out such a scheme. It would be difficult, for instance, to attract really good research staff to work which was limited to the " problems of prescription ": these are but one aspect of the much larger problem of industrial disease, a subject which hitherto has not been effectively tackled for lack of a complete organization for the purpose, and this in no way reflects on the excellent work of the Medical Research Council in this field. Other Government

departments as well as employers and employees have a direct interest in this work and all should be prepared to join forces and resources in setting up an organization which would link factory floor with research laboratories for it is here that the greatest need lies. In this way not only could the problems of prescription be studied but many of them could be made to disappear.

Conclusion

After considering this thorny subject for two years the Committee decided to leave matters alone. While aware of the defects of the present scheme they were unable to suggest anything better. They recognized that the real problem of the future was to identify, with a satisfactory degree of precision, those cases of industrial disease which present as common illnesses.

There is no simple answer to this difficult problem but much could be done towards solving it if it could be tackled by well-trained and efficient teams but unfortunately these are not available at present. Medicine has neglected this field to which it has devoted too few of its resources both of brains and money. The Beney Committee has rightly called attention to this gap in medical knowledge. It is essential that small occupational groups with risks of contracting common diseases because of special hazards should be identified and separated from the large group of patients presenting identical symptoms. This work is important, not only for the administration of the Industrial Injuries Act but for the purpose of prevention. Indeed, if it were not for the preventive aspect the simplest way of dealing with the administrative problem would be to give the same benefit to occupational and non-occupational cases. Many of the arguments against this simple solution are rooted in the past and should no longer determine policy. Perhaps some future committee set up to consider the working of this Act will be specifically charged to examine the possiblity of this major change.

BOOK REVIEWS

Ageing in Industry. By F. Le Gros Clark and Agnes C. Dunne. (Pp. x + 146 + appendix and index. 6*s*.) London: The Nuffield Foundation. 1955.

New Jobs for Old Workers. By F. Le Gros Clark and Agnes C. Dunne. Free. 1955.

The Employment Problems of Elderly Men. By F. Le Gros Clark. Free. 1956.

These three reports, all issued by the Nuffield Foundation, represent the most recent British contribution to the study of ageing in industry through detailed examination of official figures. The first two documents are based on the relevant census tables for 1921, 1931, and 1951, while the third uses Ministry of Labour and National Service records. The object of the first study was to determine " what numbers of workers are physically able to continue in their various occupations beyond their mid-sixties "; that of the second and third to inquire into " what alternative or modified jobs are actually available for older men ".

Ageing in Industry consists mainly of a detailed survey of census figures relating to 32 selected occupations. The choice of occupations rather than industries has everything to recommend it if one accepts the fundamental importance of the " actual nature of the job " a man does when trying to ascertain how long he can carry on at work.

The authors are also to be commended for their realization that " all industrial studies of this kind must have a practical aim " and for their determined effort to be lucid in presentation. The selected occupations were chosen by reference to fairly unambiguous criteria, and are precisely defined by the official census " classification of occupations ". The basis of the authors' method is to take the members representing an age-group of men in a specified occupation at the date of the 1921 census, and to bring forward this number as an expected population for the appropriately older age-group at the 1931 census. It is then compared with the actual numbers of men found in that age-group, and attempts are made to account for the observed difference. In doing this, the expected or brought-forward figure is in effect reduced by the number of men who have died or become wholly unoccupied (" retired "), though in fact the authors made this adjustment in a rather more roundabout fashion. If the adjusted " expected " figure is greater than that actually found in the 1931 census, the discrepancy is styled " unaccounted for ", and reasons are put forward for regarding this as a (maximum) estimate of those who have changed their occupation between 1921 and 1931. Where the 1931 figures are greater, the difference is referred to as " intake ". It will by now be apparent that this use of differences is not quite what it seems at first glance: like the balance in a profit and loss account, the intake is really the excess of intake over outgoings, and conversely the " unaccounted for " figure represents an excess of outgoings over intake. To be fair, the authors do start off by referring to " overall intake ", but this is tiresome to continue and the reader could easily miss the point. The actual figure for 1931 is then shifted forward to become the expected figure for 1951 for the age-group 20 years older, and the process of comparison is repeated.

The second exercise carried out by the authors is to compute, at each census date, the ratios (*a*) 65 and over, to the numbers 35-64; and (*b*) 55-64 to the same base, 35-64. Thirdly, they examine changes in the age-structure of the 32 occupations by tabulating in age-groups the percentage increases and decreases in the numbers employed from 1931 to 1951. The results of these three exercises are then examined separately for each occupation, and efforts are made to account for variations and anomalies. For example, if a heavy net intake occurs at an age-level where this is not to be expected, an explanation is advanced which is usually based on enquiries made in industry or from Government departments.

From an impressionistic integration of all the data obtained concerning an occupation, the authors arrive at what they call " survival rates ", defined as " broad percentage values of the total numbers of men we know to have reached their mid-sixties while still in their accustomed jobs and in a reasonable state of working efficiency ". That the integration is impressionistic cannot be doubted if one quotes from the text (p. 136) in respect of coal-mining:

> " All the evidence suggests that a considerable number of men gravitate [*sic* !] in their later working lives from the coal face to the surface: they may move to a lesser extent to other work below ground. A proportion of them, of course, stay at the coal face until they retire. *To judge from the figures, it seems improbable that nowadays the survival rate at the coal face can be much more than* 5-15%; the changed methods of working are beginning to make a difference " (reviewer's italics).

These estimated survival rates are then assembled in a comprehensive table (pp. 140-141) and the figures are there described as representing " not the proportion of men who *do* at present carry on beyond their mid-sixties, but the proportion who probably *could* carry on under suitable conditions " (authors' italics).

By now it will be realized that *Ageing in Industry* is extremely difficult to evaluate fairly. If one uses the criterion suggested by the actual use of officially based

figures, then, although these are clearly presented and dealt with, the conclusions drawn are not based on them directly, but rather on adjusted figures which depend on estimates and assumptions. This being the case, it seems preferable to use a different criterion as well, and to evaluate the conclusions more in terms of the shrewdness with which the authors have handled their imprecise figures. Provided, for example, one does not take the actual numerical survival rates too seriously, it seems reasonable to accept the broad implications of the table which they are used to produce. In this table one finds makers of watches and clocks and of musical instruments, together with workers in precious metals, at one extreme of occupational viability in the mid-sixties; the other end is represented by coal-face workers and railway signalmen. What the present writer finds hard to follow is the reasoning of the authors when they insist repeatedly that these survival rates represent " the proportion who probably could carry on under suitable conditions ": it is here that the presence of the original tables becomes more of an embarrassment than a help. Those original figures must by their very nature refer only to the proportion who actually do carry on until their mid-sixties without dying, giving up work altogether, emigrating, or changing their occupation. The transition to the authors' table of comparative survival rates for the 32 selected occupations must therefore be an exercise (of an admittedly high order) in the weighing of other relevant evidence in such a way as to permit the shift from " actually do " to " probably could ".

Turning to *New Jobs for Old Workers* we find a similar approach. The authors start with census figures for 16 occupations " of the kind to which men are known or commonly suspected to move in their late middle lives ". They then give good reasons why they " must necessarily have recourse to conjecture ", and consistently with this, the detailed examinations of the census figures for each occupation regularly contain phrases such as " the figures suggest ", " we have the impression ", or " there is some probability that ". All this must sound like destructive and damaging criticism unless it is made absolutely clear that in the opinion of the reviewer the census information simply does not lend itself to definitive statements: it must be illumined by some such process as that adopted by the authors of these reports. They are not always successful in showing how their rough estimates have been derived logically and computed from the figures in the tables: the reader must often take such a derivation on trust, though like the reviewer he may sometimes baulk. No, these studies must be regarded as brilliantly suggestive interpretations; the association between figures in the table and the final estimate at least serves to ensure that the interpretations will never be wild.

The third report, *The Employment Problems of Elderly Men*, is based on a study of the placing records of 141 labour exchanges during the month October-November, 1954. It is " mainly concerned with an analysis of the transitions " apparently being made by 537 men aged 60 or over who were placed in jobs which could be described as of " a lighter nature ". The author, with characteristic responsibility, makes it clear that the men who under present conditions turn up at labour exchanges are " rarely typical of any branch of industry or any social group ". Most of the 537 men were finding their way " either to light labouring jobs in factories or to one or other of the occupations usually reckoned suitable for older men ". The author makes the extremely important point that at present little or no effort seems to be made to train older men for alternative work, and he seems justified in his expression of anxiety about the continuing tradition of " old men's jobs ". He ends by suggesting " as a working hypothesis that somewhere around 15 or 20% of all men in their early and mid-sixties probably need to be given either the chance of a new job or working conditions better suited to their age ", and adds significantly, " Against this yardstick of demand we should have to measure the current supply of lighter jobs available in the country."

These reports (especially the second and third) should be read by every industrial medical officer in the country —and in particular by those who are still caught in the tradition of " old men's jobs ".

ALASTAIR HERON

Guiding Principles for the Organization of Occupational Medical Services in Places of Employment. Reprinted from *Occupational Safety and Health*, Vol. V, Nos. 2-3. April-September, 1955. (Pp. 10. 9d.; 15 cents.) Geneva: International Labour Office. 1955.

This publication which, perhaps, is intended for use in countries where the occupational health services are less well developed than in Britain can be read with advantage by any doctor working in industry, or in practice in an industrial area where he comes in contact with some of the problems of the health of work-people.

It lays emphasis on the need for catering for small undertakings, but does not suggest the solution. The present enquiry being undertaken by the Ministry of Labour may throw some light on the needs of smaller industries and how this problem can be solved.

This report draws particular attention to some of the quasi-medical functions of occupational health services which are frequently considered to be no part of the industrial medical officer's job, although his training has equipped him to give this advice. For example, it is extremely difficult to persuade the most enlightened management of the need for consultation with the industrial medical officer at the planning stage of a new factory building or process; too often many factors which, though not always dangerous to health but giving poor working conditions, are only discovered after a new process or factory is in operation. Often elementary knowledge of anatomy and physiology has to be applied to machine and building design.

The need for the industrial physician to have access at all times to all parts of the plant seems too obvious to mention, but the need is equally great for the industrial nurse, and at times, working alone without a medical officer, she may be confined to her surgery and be most unwelcome in the plant.

The section covering first-aid requirements restates the need for standards of proficiency and retraining courses; it is a pity that a definite time limit is not put

upon the period of validity of first aid certificates as this is already one of the great loopholes in the existing legislation in this country. Two years seems to be the longest possible time compatible with reasonable competence.

One of the most valuable measures described in this document is the need for producing an annual report for the management. This exercise in itself affords the industrial medical officer an opportunity of taking stock of his usefulness to the industrial community, and it gives him the satisfaction of knowing that he has achieved something within the preceding 12 months. Its value, perhaps, is greater to him than to the management to whom it is presented. It should contain not only the historical record of what has happened already, but also some commentary on recommendations for the future. Managements today are swamped with statistical information of the day-to-day production problems and have little time to study much of the detail which can go into annual reports. The need is for a brief summary of the main conclusions to be drawn from the figures presented, and one of the difficulties that exists in British industry is lack of any standardized method of recording and analysing this information. Invariably the manager wants to know, " How does my factory compare with similar industries ? ", and he has always read some other statistics in the daily press (which may indeed be misquoted). This is a great hazard in presenting reports, but it should not deter the medical officer.

The report contains invaluable information for anyone connected with the health problems of an industrial community, and it should be circulated amongst industrialists. It contains, as an appendix, the functions of industrial medical services as described by the American Medical Association, and has a useful bibliography.

J. C. GRAHAM

Psychotherapy and Personality Change. Edited by Carl R. Rogers and Rosalind F. Dymond. (Pp. x + 447. 45*s*.) London: Cambridge University Press. 1955.

This must surely set a new standard of honesty in reporting research, at least so far as books rather than articles are concerned. Honesty, though always welcome and refreshing, can, however, be naïve; this example is not. The authors and editors are not only mature enough to state clearly the faults of their methods and the limitations of their findings, but also competent enough to know what should have been done had circumstances permitted it. Amidst such evidence of merit, has the book then no faults ? Assuredly it has, and of these one of the most serious is its title. What is so fully evaluated in the book is not just " psychotherapy ", but rather that particular form of it which is called " client-centred " or " non-directive " therapy. What is described as " personality change " is probably something rather less far-reaching and dramatic than one might imagine.

This is the story of a determined effort to answer the two questions, " Does non-directive psychotherapy cause significant changes in the feelings and behaviour of patients complaining of psychological difficulties ? " and " Can these changes be demonstrated in a rigorous and objective manner rather than by appeal solely to clinical opinion ? " If the plain man asks for a definition of non-directive psychotherapy, the simple answer is that it is a method which depends upon the creation of a permissive, uncritical climate in which the patient can feel able to express his difficulties. The counsellor (therapist) refrains from offering advice or interpretations, but rather " feeds back " to the patient a paraphrase of what he has just tried to say. Speaking detachedly, the process may be described as one in which communication is progressively improved, the measure of improvement residing, however, in the patient as the communicating source; he is the " centre " or *locus* of the process. Such a process requires much more skill, patience, and humility from the therapist than is sometimes supposed.

The Counseling Centre of the University of Chicago, where these researches were carried out, " serves both the students of the University and the general public. Most clients are self-referred, although we get referrals from physicians, psychiatrists, clergymen and various community organizations ". The Centre avoids accepting a client " who might possibly require institutional treatment " and " lets it be clearly known that they cannot be responsible for medical problems ". From this it may reasonably be inferred that the subjects of this attempt to evaluate the non-directive method of psychotherapy were mainly people in psychological difficulties of the minor but often persistent kind so very commonly encountered in the surgeries of general practitioners and industrial medical officers. This makes the findings of greater interest to readers of this *Journal* but of considerably less significance to those dealing with more serious cases of neurotic or psychotic disturbance.

The research design, while representing a considerable improvement on anything hitherto reported, leaves a good deal to be desired, particularly because the ethical exigencies of the situation prevented the investigators from withholding therapy for longer than 60 days in the case of the control group of clients. This becomes serious when it is realized that the " non-wait ", or experimental group, remained in therapy for periods varying from a minimum of six weeks to a maximum of about six months. The absence of significant changes in six weeks of waiting cannot be compared with significant changes after six months of therapy so as to permit the conclusion that no spontaneous remission took place: it might have been demonstrable during six months of waiting.

The methods of evaluating change, while again an improvement on anything previously available, still include subjective elements, but the clear and full presentation of the data and the use of various measures in combination do much to meet this criticism. When ratings and judges were used, the " inter-rater " and " inter-judge " correlations were usually commendably high; when this was not so, an adequate and often convincing theoretical argument (not defensive in character) is provided so that the reader may draw his own conclusions.

It would be possible to examine the methods and findings in detail (the reviewer has in fact done so with interest), but this is probably not the place for a mass of technical evaluation and criticism. Suffice to say,

then, that in the words of Dr. Rogers (p. 433) " various changes in the self-perception of the client, in his personality organization, and in his daily behaviour occur as a concomitant of client-centred therapy ". For the reasons given above, one must suspend judgment on his conclusion " that the psychotherapy is the effective agent of change, since changes of comparable magnitude do not occur in a control group or in our clients during a control period". With some reservations, we can accept his claim that " one defined approach to psychotherapy produces certain measurable and significant changes in the individual coming for help and that certain other changes which have also been hypothesized failed to occur in significant degree ".

Not everyone will want to pay 45*s.* for this book, despite its many excellences, but every library, however small, which contains volumes on psychotherapy or neurosis should have this one too or be failing in its duty to the readers. Those who feel able to make pronouncements about the effectiveness of advice, counselling, therapy or any other brand of help for the psychologically maladjusted adult are asked to read this honest book and amend their future remarks accordingly.

ALASTAIR HERON

Mental Hygiene in Public Health. By Paul V. Lemkau. 2nd ed. (Pp. xiii + 486; 9 figures. 60*s.*; $8.00.) London, New York, Toronto: McGraw-Hill. 1955.

Dr. Lemkau's book is interesting and useful, if only for the reason that there are so few textbooks written in the English language on this important subject. The teaching is simple, but it is a disappointment on laying down the book to realize how few ideas which are really new have been presented. We know that mental hygiene and public health are team-work jobs; we have certain things to do, certain tools to use; but the reader who seeks to discover new secrets of improving mental health will not be much rewarded. There are discussion groups to be organized, or film shows, lectures, and educational programmes, the help of the churches must be sought, etc., etc., but the advice given goes little beyond the improvements of good general health, the avoidance of stress and of brain damage, and other simple teaching. The ideas are well expressed, and there is advice to encourage the " flowering of capacity ", the " correlation of life experiences ".

Perhaps, after all, it is in the science of human relationships that we shall achieve true success. But for the industrial medical officer there is little in this book which is of direct help in his daily problems. Nevertheless, the author can be praised for his courageous venture into the important field of mental hygiene in its relation to public health.

J. L. BURN

The Determination of Toxic Substances in Air. Edited by N. Strafford, C. R. N. Strouts, and W. V. Stubbings, 1st ed. (Pp. xxvii + 226; 17 figures. 35*s.*) Cambridge: W. Heffer. 1956.

For most chemists, analytical chemistry is not an end in itself but an essential tool to solve problems in other fields. When methods for a particular purpose are collected together it is essential that they should carry the authors' guarantee that they have been adapted for the purpose intended and have been adequately tested. The book under review fulfils this requirement admirably. It is intended for works' chemists in a variety of industries so that management may be able to satisfy themselves of the adequacy of the ventilation systems. The volume is a joint work of a group of 18 I.C.I. chemists, and the methods described are the result of a great deal of work on their adaptation to the determination of substances in air.

The preliminary chapter upon sampling techniques is particularly to be welcomed. This is the crucial stage of the analysis of air; it is often surprising (to the inexperienced) how inefficient badly designed bubblers can be. Again the construction of these sampling devices is given in great detail.

It has clearly been the aim of the authors that the description of a method for a particular substance should be understandable without reference to other methods. This has been a little overdone when methods are non-specific and identical reagents and procedure are used for several substances: for example, the formolite method for benzene, toluene, xylene, and chlorobenzene and the Fujiwara reaction for chloroform, trichlorethylene, and tetrachlorethane. These methods could easily and with advantage be brought together, and would have saved approximately 20 pages.

This book should prove invaluable to everyone requiring to analyse air for contaminants. The methods given are so well tried out and given with such a wealth of detail that those inexperienced in their field will find no difficulty in carrying out the analysis exactly as intended.

W. N. ALDRIDGE

Artificial Respiration with Special Emphasis on the Holger-Nielsen Method. By T. O. Garland. (6*s.* 6*d.*) London: Faber & Faber. 1955.

If ever a small scientific work written for the edification of the layman carried with it an aura of a best seller, this is it. It is an excellent little book and should become a standard textbook in school and factory. There are two schools of thought about teaching this subject. The first is for the expert to decide on the most valuable single method to the exclusion of all others, and the second is to explain the principles in a simple way so that in any situation, from the top of a pole to a small boat in a stormy sea, some real attempt may be made at getting breath in and out of the body.

Recently teaching has inclined to the former on the grounds that it is better to be thoroughly versed in one method than have a hazy knowledge of two or more. For this reason for many years Schafer's method had been the vogue generally in England and the U.S.A. whilst Sylvester's was (and is) the method of choice on the Continent. Dr. Garland has made a happy combination of the two views. He teaches the positions of the body in maximal inspiration and expiration, and shows how breathing can be enforced whether the victim is attended to while lying, sitting, or being carried.

Dr. Garland pays generous tribute to the bravery of Pask in England and the staff of the medical schools

working with the Department of Defence in the U.S.A., where volunteers were given curare, in order to test the relative efficiency of the various methods of artificial respiration. He quotes the results and from these, as is general now in the U.S.A., this country and Denmark, he favours the Holger-Nielsen method. But the importance here is that an intelligent layman may well save life when the Holger-Nielsen method is impossible, that is in situations where the patient cannot rapidly be placed in a position to receive it.

The illustrations are clear and well reproduced. The book fits into the jacket pocket, and it is certain that many a pocket will receive it.

J. P. W. HUGHES

Books Received

(Review in a later issue is not precluded by notice here of books recently received.)

New Jobs for Old Workers. By F. Le Gros Clark and Agnes C. Dunne. London: The Nuffield Foundation. 1955. Free.

The Employment Problems of Elderly Men. By F. Le Gros Clark. London: The Nuffield Foundation. 1956. Free.

Hygiène et Securité dans l'Emploi des Acides Forts. L'Acide Sulfurique. By A. Vallaud and P. Salmon. (Pp. 48; 50 figures. Fr.fr. 60.-.) Paris: Institut National de Securité. 1956.

Lung Function in Coalworkers' Pneumoconiosis. By J. C. Gilson and P. Hugh-Jones. (Pp. xii + 266; 15 plates. 21*s*.) London: H.M. Stationery Office. 1955.

Can T.B. be Prevented? Annual Report 1954-1955. (Pp. 60.) London: The National Association for the Prevention of Tuberculosis. 1955.

X-Rays: Their Origin, Dosage, and Practical Application, 7th ed. By W. E. Schall. (Pp. vii + 33; 339 diagrams and plates. 42*s*.) Bristol: John Wright. 1956.

Psychological Tests for Accident Proneness and Industrial Proficiency. M.R.C. Mem. No. 31. By E. G. Chambers. (2*s*.) London: H.M. Stationery Office.

Physics Psychology and Medicine: A Methodological Essay. By J. H. Woodger. (Pp. x + 146. 8*s*. 6*d*.) London: Cambridge University Press. 1956.

Airborne Contagion and Air Hygiene. By William Firth Wells. (Pp. xxix + 423; 32 figures. 48*s*.) London: Oxford University Press; Cambridge, Mass.: Harvard University Press. 1955.

Peaceful Uses of Atomic Energy: Vol. 10—Radioactive Isotopes and Nuclear Radiations in Medicine. (Pp. lx + 544; illustrated. 57*s*.; $8.00.) London: H.M. Stationery Office; New York: United Nations. 1956.

THE APRIL (1956) ISSUE

The April (1956) issue contains the following papers:—

Aluminium Powder Inhalations in the Treatment of Silicosis of Pottery Workers and Pneumoconiosis of Coal-miners. By M. C. S. Kennedy.

Death Rates of Miners and Ex-miners with and without Coalworker's Pneumoconiosis in South Wales. By R. G. Carpenter and A. L. Cochrane, with the assistance of W. G. Clarke, G. Jonathan, and F. Moore.

Mucous Flow and Ciliary Activity in the Trachea of Rats Exposed to Pulmonary Irritant Gas. By Tore Dalhamn and Johannes Rhodin.

Two Cases of Meta-dinitrobenzene Poisoning with Unequal Clinical Response. By Tihomil Beritić.

A Social and Occupational Study of Injured Hands. By Ruth Wilkes.

Consistency and Car Driving Skill. By R. E. F. Lewis.

Miscellanea:

John Darwall, M.D. (1796-1833) and "Diseases of Artisans". By A. Meiklejohn.

British Occupational Hygiene Society: Ordinary Scientific Meeting.

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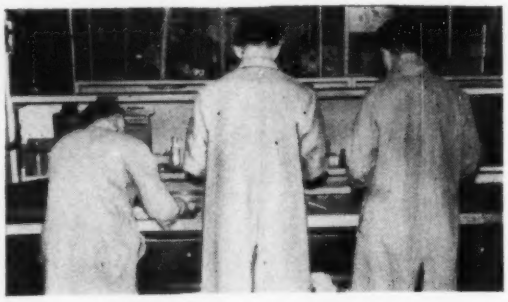

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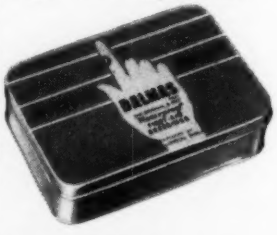

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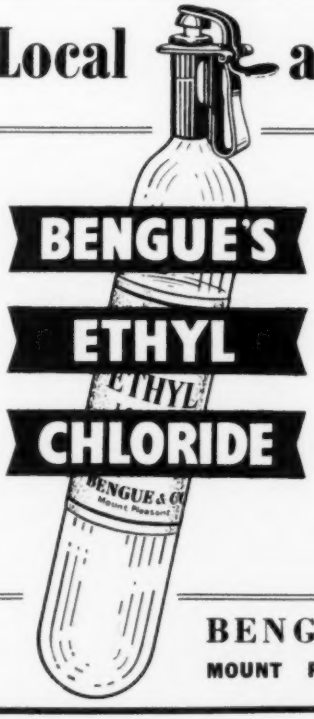

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